The
ENGINEERS' DIGEST

A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 6 JUNE, 1960

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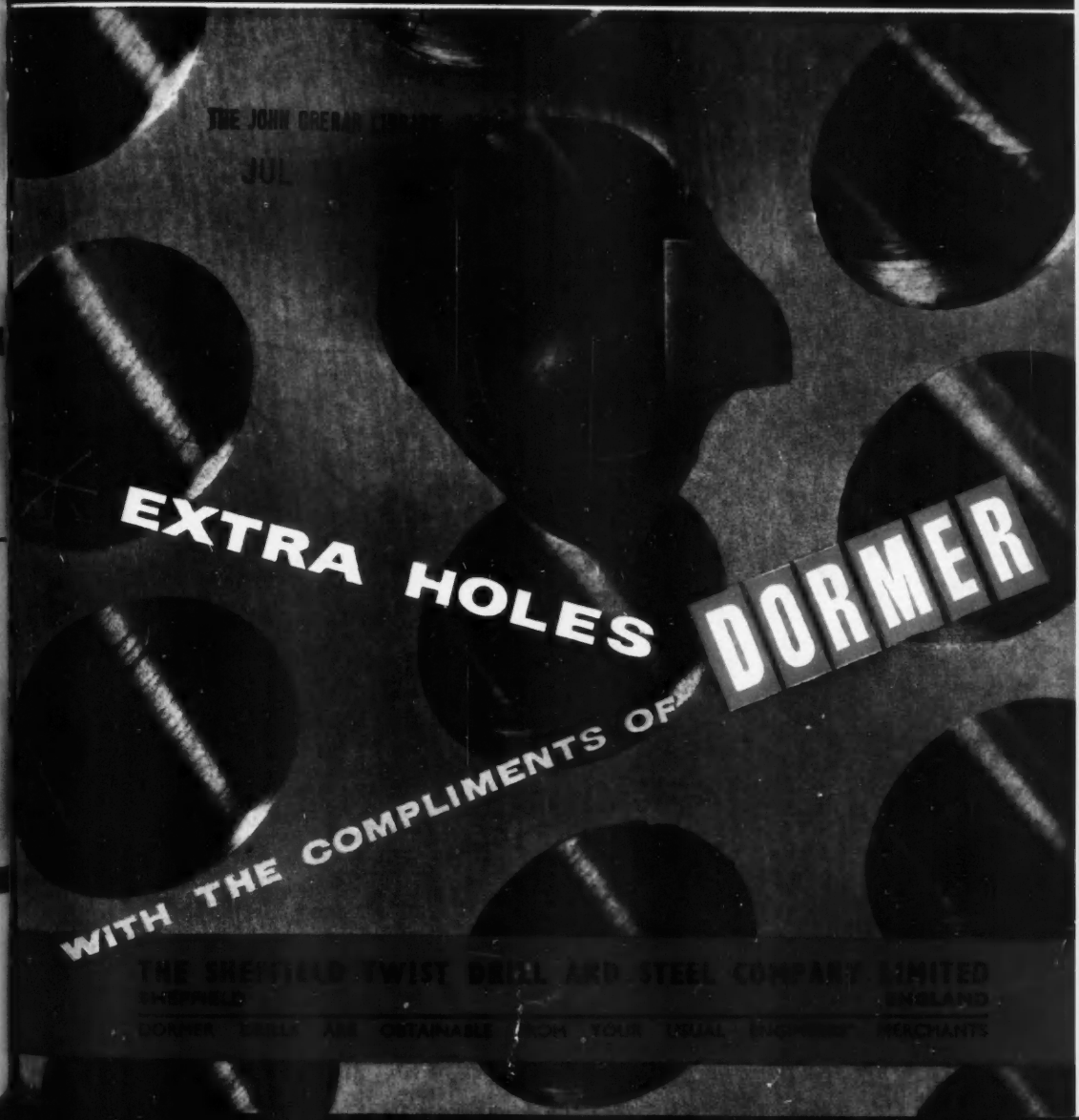

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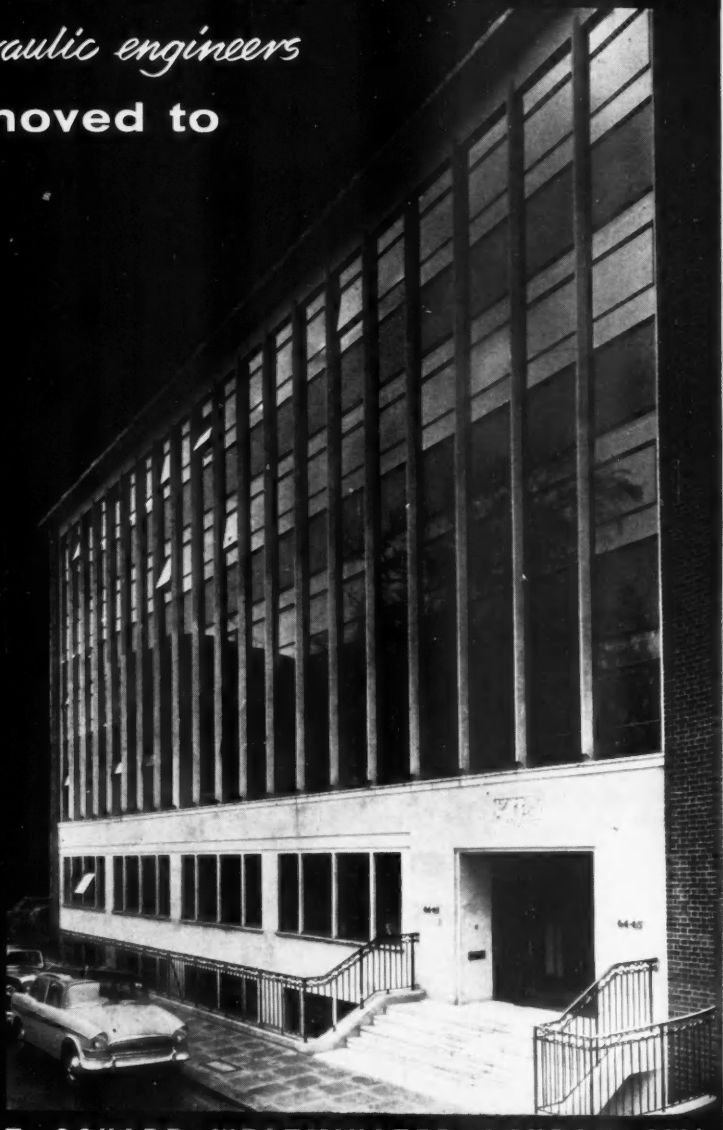

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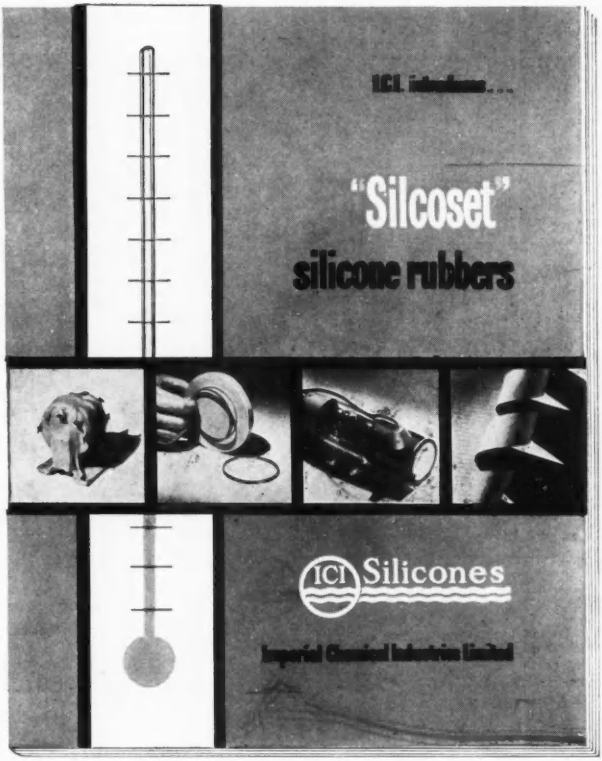

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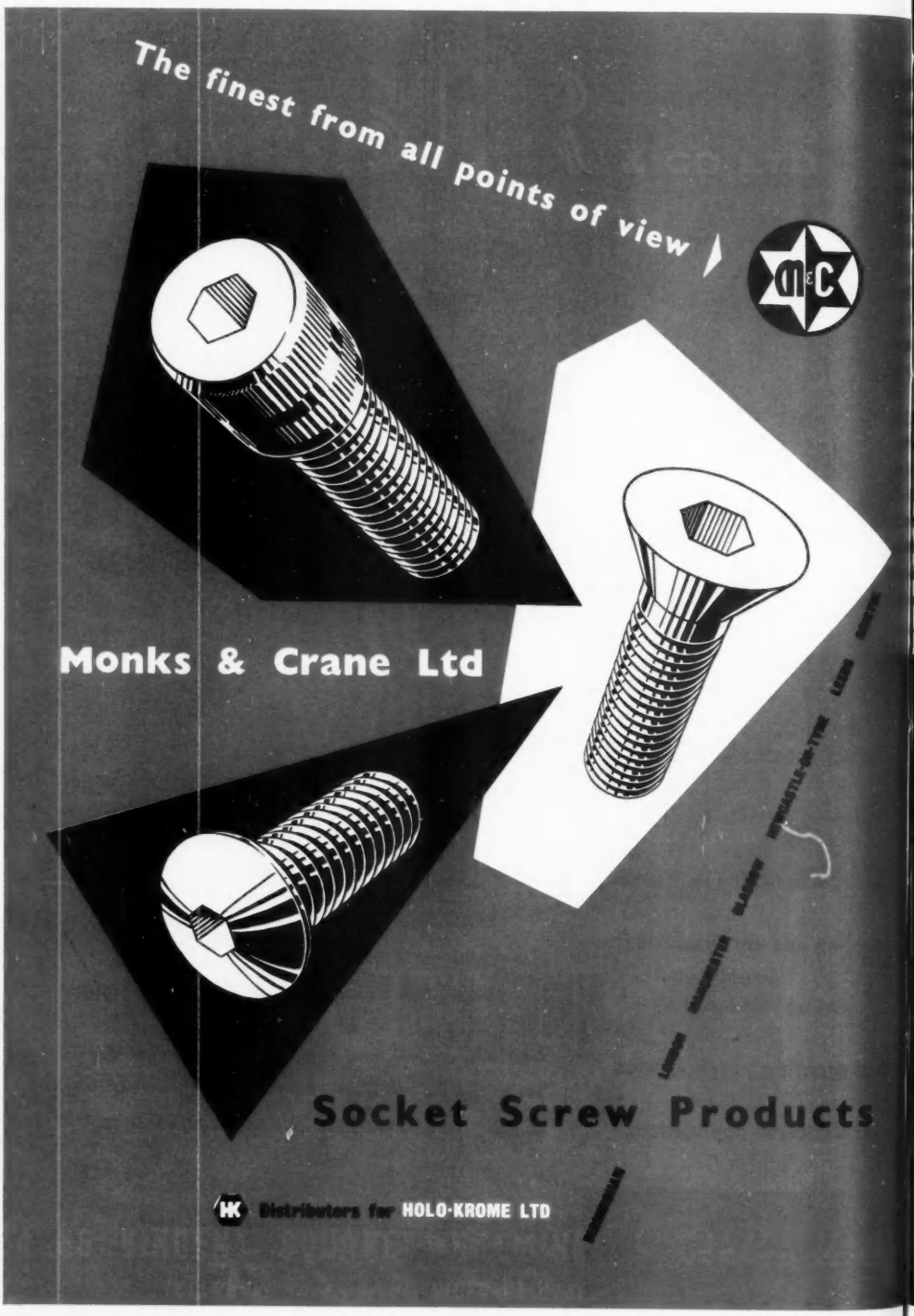
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The ENGINEERS' DIGEST

A World Review of DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

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A new **high-speed electrical stroboscope** or sampling oscilloscope, developed by the Bell Telephone Laboratories, of New York, has an effective band width of the order of 5500 megacycles and a rise time in the range of a fraction of a millimicrosecond. In this instrument, a gallium arsenide crystal is used as a gate which is opened briefly by pulses from a high-speed pulse generator to observe short samples of the signal pulse. The final signal, observed on a low-frequency oscilloscope display tube, is the result of integrating a large number of these samples, this integration taking place in a somewhat similar manner to the fusion of samples in the eye when watching an optical stroboscope. The instrument, which is purely a development model and which is not yet available commercially, is being used in studies of binary pulses in the range of 10^9 bits per second and has an overall sensitivity of 2 mV/cm. Tests indicate that rise times at least as short as 1×10^{-10} sec can be displayed satisfactorily.

* * *

According to an article in the German Journal *Aluminium* for May 1960, investigations have been carried out in Germany into the **influence of temperature and electrolyte concentration on the growth of anodic films on aluminium.** It has been established that only slightly porous films are produced in electrolytes which have practically no solvent action, whereas highly porous films are developed in such electrolytes as sulphuric acid which are capable of dissolving the incipient films. Under conditions of equal temperature, films of varying pore size and electrical resistance can be obtained, both pore size and resistance depending on the concentration of the electrolyte.

* * *

As reported briefly in *Machine Design* (April 28, 1960), a **new moulding process** makes it possible to produce pure nickel moulds, tools, dies, patterns, or almost any complex shape without any need for machining. In this new technique, which is designated the Budd carbonyl metal process, carbon dioxide serves as the "driver", forcing nickel-carbonyl liquid to flow into a vaporizer and then, as a gas, into a depositing chamber, where pure nickel shells are formed. It is claimed that the new process not only saves time and costs, but has a number of important advantages. Thus, the finished carbonyl-nickel product has about five times the

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resistance to sand abrasion as cast iron, and is also superior to aluminium, bronze, and chrome-vanadium steel in this respect. Furthermore, it has an extremely smooth surface and, in forming-die applications, will not "cold-weld" or otherwise score sheet metal during working, while its high thermal-shock properties (up to 1600°F) permit rapid cooling or quenching.

* * *

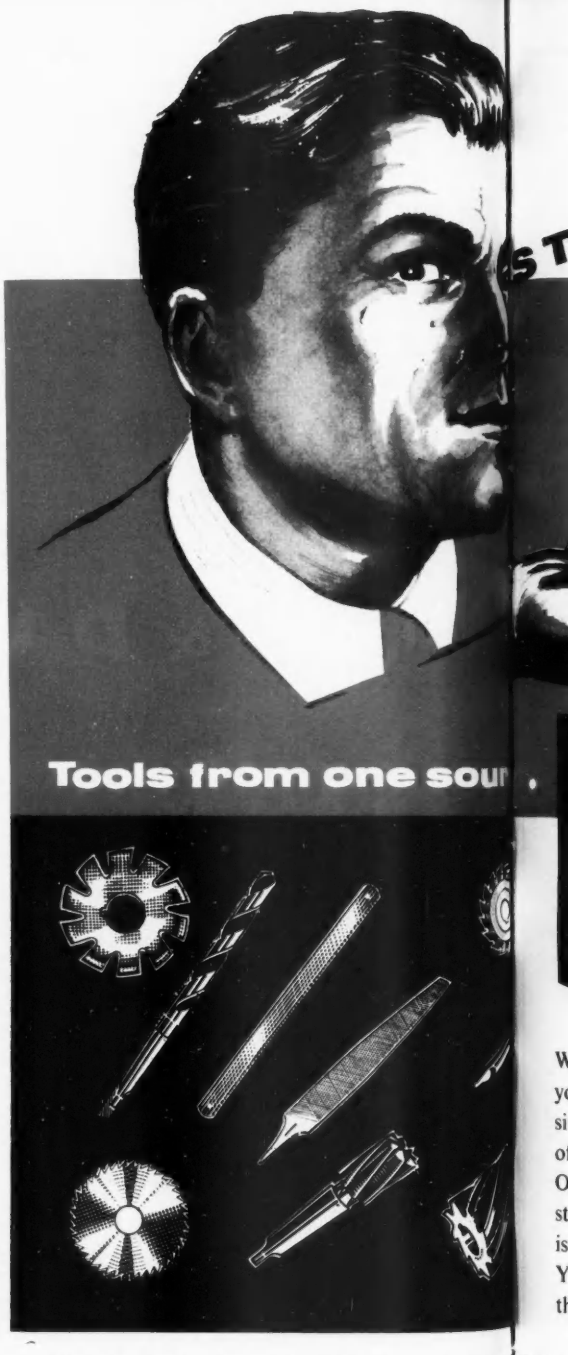
Although electronic methods of measuring distances have been developed and have been applied to geodesy, they are not always successful when the highest degree of accuracy is required, one of the main disadvantages of purely electronic methods being that ground reflections affect the final results. In this connection, the Royal Institute of Technology, Stockholm, has been engaged since 1951 on a research programme of **electro-optical methods of measuring distances** and has recently described an instrument, designated the "Terrameter", in which the phase of the electrical oscillation of a quartz crystal is compared with the phase of a photosignal from the reflected wave. Two different designs have been tested, in one of which the standard deviation over a distance of 1 km does not exceed ± 11 mm.

* * *

Based on the use of photosensitive resins which polymerize on exposure to light, a number of **photographic methods requiring no processing** to produce an image are being investigated by an American company on behalf of the U.S. Air Force, not only to determine their suitability for aerial reconnaissance, but also with a view to their possible commercial utilization. As soon as polymerization of the photosensitive resin takes place, the photograph virtually develops itself and requires no further processing, so that, in effect, a system of "instant" photography is obtained.

* * *

It is reported in *Stal* for April 1960, that present methods employed in Russia for producing vanadium in rotary kilns have a number of shortcomings, including a low rate of metal recovery and operational troubles, mainly owing to the complexity of the chemical reactions involved. It is now claimed, however, that these difficulties have been overcome experimentally by means of a **fluidized-bed process for producing vanadium,** in which finely ground vanadium ore is fed into a shaft furnace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The MINIDIGEST

with additions of sodium sulphate or sodium chloride, this mixture being heated to between 800° and 850°C approximately to form a fluidized bed, where calcination is completed in about 90 min. It is stated that the duration of this process is considerably shorter than with conventional methods, while the rate of metal recovery is from about 5 to 7% higher. In addition, the solid residue contains only an insignificant amount of vanadium pentoxide.

* * *

A brief note in *Electronics* (March 18, 1960) states that, following research by Electro-Optical Systems, of Pasadena, Cal., it now appears that **new applications for exploding wires** are feasible, including their use as high-intensity light sources for communications purposes and as propulsive devices for vehicles in outer space. In addition, their possible use in hypervelocity particle impact research and as a means of fusion in the generation of thermonuclear energy is envisaged. These applications are based on techniques which have been developed for switching extremely large amounts of current into thin wires in times of the order of a millimicrosecond. This rapid switching ability has evolved from work carried out in connection with the development of a 5-millimicrosecond Kerr-cell camera, and permits many times the vaporization energy of the material to be directed into the wire, creating temperatures above 100,000°C and pressures in the megabar range. Specific impulses of 1000 sec have been achieved in an exploding aluminium wire, and an impulse range of 1000 to 5000 sec appears possible.

* * *

Suitable for use in small refrigerators up to 4 cu ft capacity, **new thermoelectric cooling units** using crystals of bismuth telluride are stated by the manufacturers, the Materials Electronic Products Corporation, of Trenton, N.J., to provide an efficient and extremely economical refrigeration system. In this respect, the bismuth telluride crystals, which can be produced in lengths up to 18 in., have a cooling efficiency of about 60% that of a comparable mechanical compressor unit, but this is largely offset by the fact that the cooling units incorporating them are of extremely simple design, basically comprising *p-n* couples in series and copper electrodes, with leads connected to a matrix, the thickness of which can be varied in accordance with the required load.

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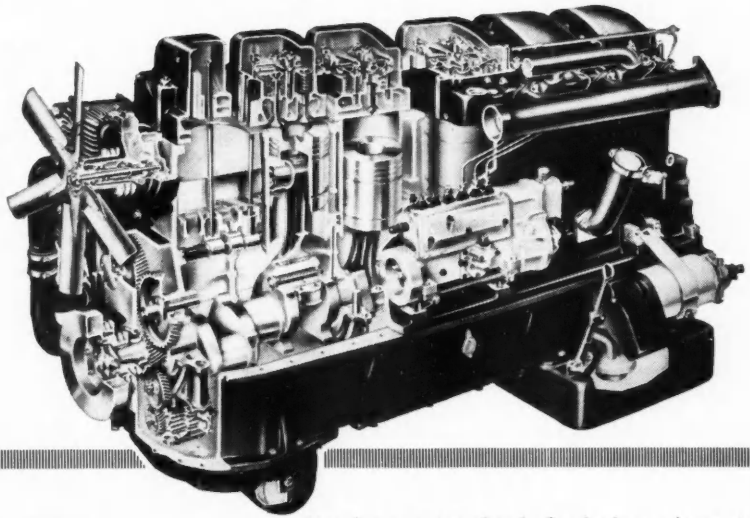

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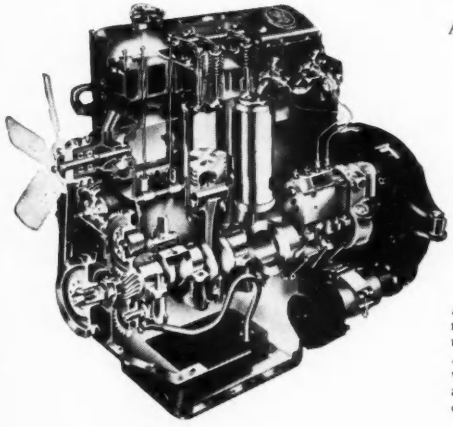

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BUSINESS NOTES

It is announced that **British Ropes Limited** have completed negotiations with the new Zealand Government to set up a factory in Auckland to supply the major part of the domestic needs of New Zealand for wire ropes.

* * *

Brayshaw Tools Limited announce that their new London address is 232 Bishopsgate, London. E.C.2. (Tel: BIShopsgate 3575/6.)

* * *

Following negotiations for the acquisition of new premises for the company and its subsidiaries, **Specialloid Limited** are now occupying the front portion of Airedale Works, 160 Hunslet Road, Leeds 10. Covering an area of just over five acres, these works will allow for continued expansion of production and sales activities, and a considerable portion is already equipped with plant which is in full production. The telephone number (Leeds 31471) and the Telex number (55-108) of the new address remain unaltered.

* * *

The Plessey Co. Ltd., of Ilford, Essex, announce that, following a licence agreement with **Précision Mécanique Labinal,** of Paris, they are now commencing manufacture of a range of aircraft constant-speed alternators embodying the "Labamatic" principle of constant-frequency control, which is based on an electromagnetic coupling incorporated in the drive to the alternator shaft. At the moment, these machines have been developed for the power range between 4 and 19 kVA, but units of up to 35 kVA are currently being investigated. The 4-kVA unit, which has been operating successfully for some years in French fighter aircraft, is designed to function at altitudes up to 55,000 ft with forced-draught cooling and will withstand accelerations up to 15 *g* in all directions

* * *

British Insulated Callender's Cables Limited announce the formation of a new company, **Telcon Metals Limited.** This company, centred at Crawley, assumes responsibility for all the activities of the Metals Division of **The Telegraph Construction and Maintenance Co. Ltd.,** including the manufacture of Telcon magnetic materials and other special alloys used in the electrical and engineering industries, and also the advanced metallurgical operations associated with them.

* * *

Developed in the U.S.A. by **Aldridge Industrial Oils, Inc.,** quenching oils containing "Quenzine", which is a formulation of wetting oils and other ingredients, are now being made and marketed in the U.K. by the **Electric Resistance Furnace Co. Ltd.,** of Weybridge, Surrey.

* * *

The **Davy and United Engineering Company Limited** announce that they have formed a Steel Processes Division to absorb the personnel and to carry on the work previously undertaken by **Davy British Oxygen Limited,** who were established jointly by Davy-United and

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* * *

To satisfy more fully the requirements of the agricultural-machinery industry, the experience of two leading companies in their field, i.e., **Hardy Spicer Limited** in England, and **Jean Walterscheid KG** in Germany, has been co-ordinated by the formation of a technical sales organization to be known as **Hardy Spicer-Walterscheid Limited.** The new company, whose address is Chester Road, Erdington, Birmingham 24 (Tel: Erdington 2191) will be responsible for marketing in the U.K., the Commonwealth countries, and certain other overseas territories the range of agricultural products, including drive-shafts and universal joints for all types of agricultural machines driven by power take-offs, produced by the two companies.

* * *

A new company in Africa is announced by **Leyland Motors Ltd.** to cover Kenya, Uganda, and Tanganyika, where some 2000 Leyland Group vehicles are already in operation. The new company, which will also handle sales and service in Somalia and which will shortly appoint a concessionaire in Mogadiscio, will trade until the title of **Leyland Albion (East Africa) Ltd.,** with head office and works in Nairobi. Directors of the company are Sir Henry Spurrier and Mr. J. L. Blackwood Murray, Leyland's resident director in Southern Africa.

* * *

The Industrial Fan & Heater Co. Ltd., one of the members of the **Simms Group** of companies, have moved their London headquarters from Barnet to Remax House, Alfred Place, London, W.C.1 (Tel: LANgham 9561).

* * *

A subsidiary company in India, to be known as **Atlas Copco India (Private) Ltd.** is to be established by **Atlas Copco AB** at Poona, about 120 miles east of Bombay. The new factory, which is scheduled for completion by the end of 1960, will produce air compressors and pneumatic rock drills. The chairman of the board will be Mr. Akbar Hydari.

* * *

An agreement has been concluded between **Ferranti Ltd.,** of Hollinwood, Lancs., and the **Bendix Aviation Corporation,** one of the leading American manufacturers of machine-tool control systems, for the sale in the U.S.A. of the new Ferranti systems of machine-tool control developed in Edinburgh.

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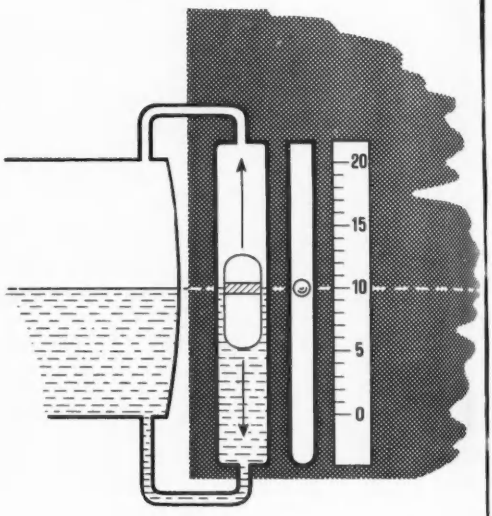

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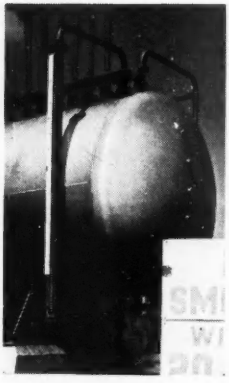

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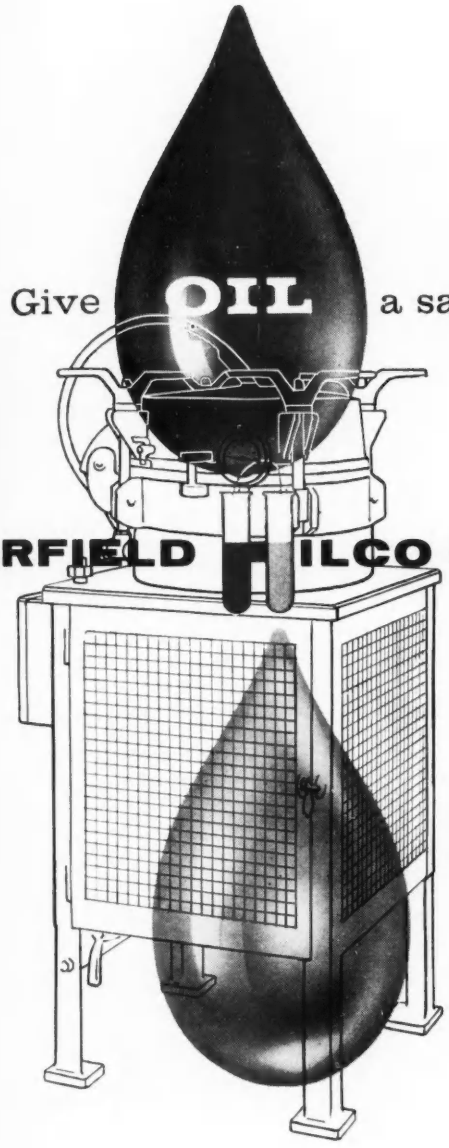

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CONTRACTS

Gresham Transformers, Ltd., of Twickenham Road, Hanworth, Middlesex, have just built what is believed to be the world's largest electromagnetic control system or transductor. This equipment, which weighs over 20 tons, will be used in conjunction with germanium rectifiers manufactured by the Westinghouse Brake & Signal Company, Limited, to control an output current of 12,000 A, and is intended for research work in Holland. The value of the order is £17,500.

* * *

An order worth over £300,000 for high-voltage testing equipment has been placed with Ferranti Ltd., of Hollinwood, Lancs., by the U.S.S.R. The equipment, which will be used in testing high-voltage cables, includes two d.c. testing units, one giving an output of 2,000,000 V; six a.c. testing units, including one with a rating of 3000 kVA at 1,500,000 V, and another with a rating of 4500 kVA at 750,000 V; and one 3,600,000-V impulse generator. This is the largest contract for high-voltage testing equipment of this type ever placed with a British manufacturer.

* * *

The Plessey Company Limited, of Ilford, Essex, have received a contract valued at £700,000 for the supply of aircraft generation systems for the Vickers VC.10 jet airliner. The first 35 of these aircraft have been ordered by B.O.A.C., and delivery will start in 1963. This contract follows a new licensing agreement now concluded between Plessey and the Westinghouse Corporation, U.S.A., allowing Plessey to produce and market throughout the world—apart from U.S. territories and Canada—these Westinghouse systems.

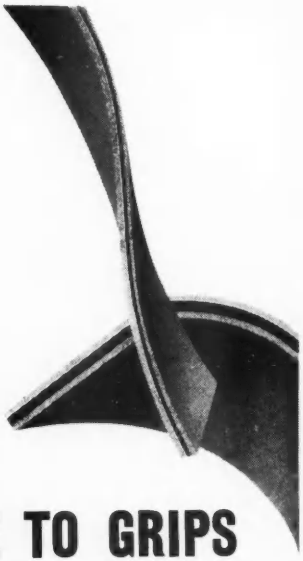
* * *

Film Cooling Towers (1925) Limited, have been informed by the Central Electricity Generating Board that they have been awarded a contract, valued at about £600,000, for three 4,800,000-gph natural-draught cooling towers to be erected at Thorpe Marsh Power Station, near Doncaster. Each tower will be 350 ft high.

* * *

Rose, Downs and Thompson Limited of Old Foundry, Hull, a member of the Power-Gas Group, have received two contracts valued at nearly £200,000 for complete vegetable-oil mills, both of which incorporate refining and deodorizing equipment. The first mill is to be erected in West Africa and will incorporate four Rosedowns "long-cage" *D*-type "Maxoil-Duplex" high-pressure expellers and one "L.C." pre-pressing expeller The second mill, destined for the West Indies, will process 40 tons of oilseed per day in two "long-cage" *D*-type expellers.

In addition, the company has received a contract valued at approximately £160,000 from Kenya for a complete plant to recover crude pyrethrin extract from pyrethrum flower heads. This installation is the second which the company has supplied to their client at Nakuru incorporating a Rosedowns/Merz rotary continuous solvent-extraction unit.



COME TO GRIPS WITH BELT DRIVE PROBLEMS

NYLON-CORE FLEXIBLE BELT TRANSMITS POWER WITHOUT SLIP

The Miraclo belt represents the last word in modern belt transmission. Chrome leather bonded to nylon gives extraordinary flexibility, enormous grip and strength. Yet it's elastic, light in weight and has virtually no permanent stretch. The Miraclo belt is truly unique, and we would welcome the opportunity of proving this to you.

Stephens Belt Drive Computor FREE to Engineers and Designers.

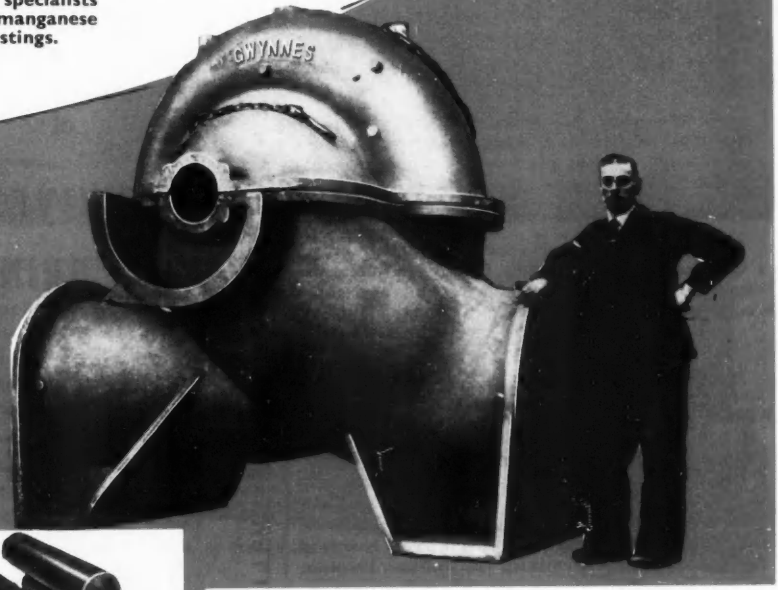
Requests should be made on business note headings.

STEPHENS Miraclo

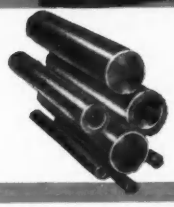
STEPHENS BELTING COMPANY LTD.
Snow Hill, BIRMINGHAM, 4
Northern Area: Ira Stephens, Ashton-under-Lyne

There's an art in CASTING

The skill needed to send a fly skimming through the air and land just in the right place is only acquired with experience and practice. The art of making good castings is equally a matter of skill and precision. We are specialists in the manufacture of manganese and aluminium bronze castings.



This intricate pump casting, reproduced by kind permission of Gwynnes Pumps, is cast in gun metal and weighs 7 tons 12 cwt.



We manufacture and stock large quantities of Chill Cast Solid and Cored Bars, supplied in 2' lengths or cut to customers' requirements—no order too small to merit our attention.

J. T. PRICE & COMPANY LTD.
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NEWCASTLE, STAFFS. Telephone: 52311-2-3

PERSONAL

It is announced by the Sperry Gyroscope Company Limited, of Brentford, Middlesex, that **Mr. R. I. T. Falkner** has joined the company as general sales manager of the Brentford Division, with special responsibility for marine and aircraft equipment. Mr. Falkner assumes the divisional responsibilities previously held by **Mr. R. E. Leete,** who now moves to the central organization, reporting directly to the managing director.

* * *

Mr. C. F. Watts has been appointed a director of Wickman Limited, of Tile Hill, Coventry.

* * *

Mr. F. M. Ryan, a director of the Norton Grinding Wheel Co. Ltd., of Welwyn Garden City, Herts., and vice-president and general manager of Norton International Inc., has retired after more than 46 years' service with the company.

* * *

British Resin Products Limited, of London, W.1, a member of the Distillers Plastics Group, announce that **Mr. G. F. Prescott** has been appointed a director of the company.

* * *

It is announced by British Insulated Callender's Cables Ltd. that **Mr. J. A. Rodgers,** formerly assistant sales manager (mining) has been appointed divisional sales manager (accessories).

* * *

Mr. I. A. Bailey has been appointed deputy chairman of the Mond Nickel Company Limited and of Henry Wiggin & Company Limited, while **Mr. E. Vaughan** has been appointed a director of both companies.

* * *

George Kent Limited of Luton, Beds., announce the appointment to the board of directors of **Mr. J. F. Willsher,** general works manager.

* * *

Dr. R. L. P. Berry, beryllium project manager since 1958, has been appointed to the board of the Metals Division of Imperial Chemical Industries Ltd. Dr. Berry has also been appointed to the delegate boards of two I.C.I. subsidiary companies, i.e., Marston Excelsior Ltd. and Lightning Fasteners Ltd.

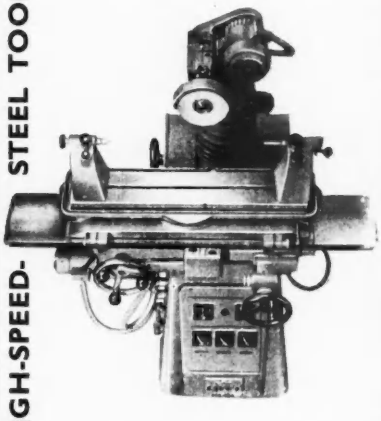
* * *

It is announced that **Mr. J. W. Ringrose** has been appointed chief applications engineer of Semiconductors Limited, and will take charge of the company's applications laboratory.

* * *

Mr. C. Dannatt, O.B.E., M.C., D.Sc., I.E.E., has been appointed vice-chairman of Associated Electrical Industries Ltd., with the special responsibility of co-ordinating

HIGH-SPEED-STEEL TOOLS • THREAD-MILLING CUTTERS • MILLING CUTTERS



For all precision tool grinding operations, wet or dry, ask us for details of

THE UNIVERSAL TOOL GRINDER

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developed by specialist tool designers

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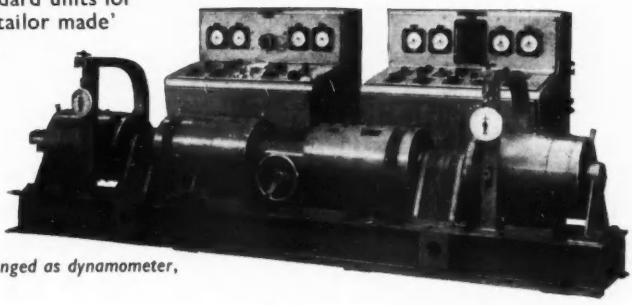
POWER AND CONTROL

E.D.C.C. machines and control gear are available to meet most requirements. Standard units for straightforward applications and 'tailor made' specials for the most diverse uses.

Recently supplied to the Welsh College of Advanced Technology, Cardiff — a multiple motor generator set, comprising 4 machines and two control desks. The machine unit comprises:—



- *7 h.p. D.C. variable speed motor, arranged as dynamometer, complete with Tacho-generator*
- *4 kVA alternator*
- *4 kVA alternator with rotatable stator*
- *7 h.p. synchronous motor (left to right) arranged as dynamometer*
- *The complete unit can be split into two motor-alternator sets*

ELECTRO-DYNAMIC

CONSTRUCTION COMPANY LIMITED

ST MARY CRAY KENT PHONE: ORPINGTON 27551 GRAMS: ELEDAMIC ST MARY CRAY

CONTROL GEAR DIVISION: BRIDGWATER SOMERSET TEL BRIDGWATER 2882 GLASGOW OFFICE: 40 HOULDSWORTH ST C3 TEL: CENTRAL 2620

P2827

PERSONAL

both commercial and technical policy. Dr. Dannatt, who is at present a director of A.E.I. and managing director of Associated Electrical Industries (Manchester) Limited, will be succeeded at Manchester by **Mr. H. West, Assoc. M.C.T., Hon. M.Sc. (Manchester), M.I.Mech.E M.I.E.E., Member A.M.E.M.E.**

* * *

Sir John Evetts, having relinquished his directorship of Rotol Limited, has now been appointed to the board of Dowty Fuel Systems Limited.

* * *

Mr. C. H. Offord, general manager of the Newhouse (Lanarkshire) factory of Honeywell Controls Limited, has been made a director of the company.

* * *

Mr. V. W. Press has resigned his position as sales director of Lancashire Dynamo Nevelin Ltd., of Oxted, Surrey, to take up a similar appointment with the Limit Engineering Group, where he will be responsible for implementing the sales-expansion programme following the acquisition of an additional factory at St. Albans. Mr. Press will operate from the Group's main office at Islington.

* * *

Cochran & Co., Annan, Limited, of Annan, Dumfries, announce the appointment of **Mr. A. D. C. Gunn, B.Sc.(Eng.), M.Sc., F. Inst. F.,** as technical director.

* * *

Short Brothers & Harland Limited announce the appointment of **Mr. E. G. Collinson, B.Sc., A.F.R.Ae.S.,** as chief mechanical engineer to the company's Aircraft Division. Mr. Collinson will be concerned with mechanical and system problems in connection with aircraft, concentrating initially on the SC.5 "Britannic', freighter, which Shorts are producing for R.A.F. Transport Command.

* * *

It is announced by Birfield Limited that **Mr. M. S. Crosthwaite** has relinquished his appointment as managing director of Hardy Spicer Ltd. and becomes this company's technical director, with the additional responsibility of advising the Birfield Group on the design and development of transmission equipment. **Mr. K. W. Evans,** formerly managing director of Forgings & Presswork Ltd., becomes managing director of Hardy Spicer Ltd., but remains on the board of Forgings & Presswork Ltd. as deputy chairman. **Mr. R. K. Johnson,** a director of Forgings & Presswork Ltd., becomes director and general manager of the company.

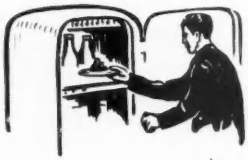
* * *

Mr. E. Greenwood, general manager of Modern Machine Tools Ltd. and of Precision Machinery Services Ltd., of Coventry, has been elected to the board of directors of both companies, of which **Mr. P. E. Verrall** is managing director.

INDUSTRIAL LUBRICANTS

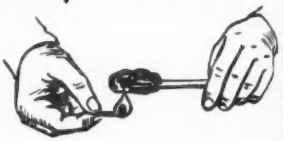
GREASES, GREASE COMPOUNDS

and Molybdenum-Disulphide (MoS_2) Specialities



Make this simple test–

and this



Prove for yourself by placing a small amount in an ordinary refrigerator—or hold over a flame.

Ask for a free sample and mention your lubrication problem.

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NEWS ROUND-UP

Extensions to the Barry Plant of Midland Silicones

It is now more than six years since full-scale production amounting to 600 tons per year of basic silicone polymer was initiated at the Barry plant of Midland Silicones Ltd. Since then, silicone products have found such ever-increasing fields of application, and developments in these fields have been so rapid that it has been found necessary to make constant additions to the plant, including a new unit for the manufacture of methyl chlorosilane, one of the primary ingredients of these silicones. Working all the year round on a 24-hr day basis, the plant now turns out some six-dozen different silicone-rubber products, whereas the former plant handled only about one dozen different products three years ago. Indeed, many of the products currently made were developed at Barry to meet the individual requirements of various industries.

A major development programme was launched two years ago with a view to doubling the output of silicone rubbers and fluids, including the construction of a new silicone-rubber plant, which is claimed to be the most modern of its kind in Europe. In addition, a new pilot plant has recently been completed at a total cost of £250,000, this unit housing the process-development group concerned with the introduction of new types of chlorosilane materials and with increasing the efficiency of current processes. Also, a new laboratory has been built and equipped for carrying out fundamental research and practical experiments on finished silicone products.

At the moment, three further projects are in hand, i.e., the building of a new warehouse, the construction of a new fluid-production unit, and the installation of additional resin-manufacturing capacity.

The World's Largest Goliath Crane

Providing an interesting and sometimes startling record of a notable and wholly successful feat of modern mechanical engineering on the grand scale, the new technical film "Goliath", sponsored by Babcock & Wilcox Ltd., of London, N.W.1, covers the design, constructional principles, and installation of the world's largest Goliath crane, erected at the Hinkley Point nuclear power station for lifting and positioning loads up to 400 tons. This gigantic structure is 250 ft in height, has a span of 250 ft, and can travel its load over a distance of nearly a quarter of a mile.

The unique principles of the crane's design and construction are clearly described by means of a model and animated diagrams, together with the use of a scale working model to investigate the major problems of erecting so large a structure on site—a task which includes the lifting into position of the 640-ton main beam of the crane, using its own hoist mechanisms.

The film concludes with a lift that approaches the full capacity of the crane, involving one of the steam-raising units, 90 ft in height and 21½ ft in diameter, which is lifted from the fabrication area, travels nearly 450 yards, and then is accurately placed on its plinth—an operation which is to be repeated as routine for all the twelve Babcock steam-raising units with which this 500-MW power station is equipped.

This sound-film, which is in full colour and is

T28
EAGLE "CHEMI ★ SEALED" TURQUOISE DRAWING HB
cleaner
sharper
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Get perfect 'originals' and first-class prints with TURQUOISE pencils. Extra-smooth TURQUOISE pencils actually ease your work! TURQUOISE lead lasts longer for every sharpening. Holds a needle point under great pressure. It's made from 100% electronic graphite to give denser, more opaque lines for cleaner, sharper reproductions. Lines rub out without a trace if required. No omissions, no fade-outs, no 'ghost' lines on your prints! 17 precise gradings from 9H to 6B.
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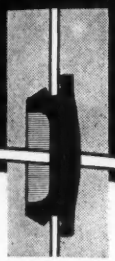
A new Grommet development

THE DOUBLE SEALING EMPIRE RUBBER GROMMET

infinitely accommodating in use: considerably reduces range of sizes because the same grommet can be used with several plate thicknesses or cable sizes



PAT. APP. No. 5255/59

This newly developed self-conforming grommet, because it is immediately self-locking against the elements, is the solution to many of an engineer's sealing problems.
Any one size will not only accommodate itself to a variety of mounting plate thicknesses, but (designed for cable or control rod) will take these in a variety of sizes and be weather-, water- and dust-proof at a variety of angles to the cable or rod.

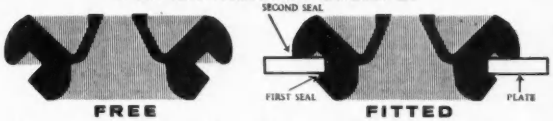
Because of its capacity to conform to many varying requirements, it enables a workshop stock range of grommets to be reduced to perhaps one tenth of that at present maintained.

THE NEW BLIND GROMMET

FREE

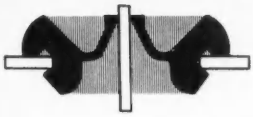
Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

THE NEW DESIGNED GROMMET



FREE FITTED

In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.



A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.

In the conventional grommet, only one thickness of plate and only one size of cable can be accommodated. No effective seal is afforded by the parallel groove.

Now being produced in a range of sizes.

THESE GROMMETS WILL SOLVE YOUR SEALING PROBLEMS.

ENQUIRE
for catalogue section and detailed particulars.

EMPIRE RUBBER COMPANY · DUNSTABLE · BEDFORDSHIRE · ENGLAND

R.B.101

obtainable in 16- and 35-mm versions, is available on free loan to colleges, engineering bodies, associations, and other organizations, on application to the London head office of the company at 209 Euston Road, London, N.W.1, or to any of the branch offices of the company.

Conference on Heat-Treatment Practice

A conference on heat-treatment practice, organized by the British Iron and Steel Research Association, will be held at Harrogate on July 5 and 6, 1960. The main aspect of the subject to be considered will be carburizing, with various papers covering the theory and practice of carburizing and the properties of carburized steels.

Full organizational details and registration forms can be obtained on application to the Technical Secretary, Metallurgy (General) Division, BISRA, 11 Park Lane, London W.1.

The Institute of Physics and the Physical Society

The incorporation of a new body on May 17, under the name of "The Institute of Physics and The Physical Society" marks the fulfilment of the desire expressed by the overwhelming majority of the members of the Institute and Society to implement the scheme for amalgamation prepared by a Joint Committee. The originating bodies will shortly be formally wound up, and their assets handed over to the new body.

The first President of the amalgamated body is Sir John Cockcroft, and the four Vice-Presidents are Dr. J. Topping, Dr. W. H. Taylor, Professor R. W. Ditchburn, and Mr. A. J. Philpot, each responsible to the Council for a defined area of the many activities to be taken over by the new organization from its predecessors. The Presidents of the predecessors (Sir George Thomson and Mr. J. A. Ratcliffe) are also members of the new Council. The other Officers are Dr. J. Taylor (Honorary Treasurer) and Dr. C. G. Wynne (Honorary Secretary).

The qualification for the award of Fellow of The Institute of Physics, Associate of The Institute of Physics, and Graduate of The Institute of Physics will remain unchanged, and members of the new body holding these diplomas will also be Fellows of The Physical Society. All Fellows of the old Society will be automatically transferred to this new grade, but new candidates for election to the grade will be required to possess a degree or diploma in physics recognized by the Council, or to satisfy the Council that they have a sufficient knowledge of physics.

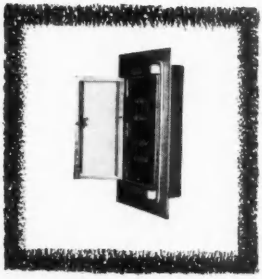
Provision has been made for other scientists and engineers to participate in the scientific and educational work of the new body. Activities relating to the practice of the profession as such will be strictly confined to those possessing one of the Institute's diplomas.

The Executive Officers of the new body are Dr. H. R. Lang (secretary), Dr. A. C. Strickland (editor and deputy secretary), and Mr. N. Clarke (deputy secretary). The registered offices and headquarters are at 47 Belgrave Square, London, S.W.1, and, for the present, offices will also be retained at 1 Lowther Gardens, South Kensington, London, S.W.7.

AEROFLEX Fluvent

CABINET STYLE DISTRIBUTION BOARDS

Widespread acceptance of surface mounting Fluvent Cabinet Style Boards has resulted in the production of Switches of similar exterior, intended principally for use as control switches mounted in conjunction with the boards. Both boards and switches have pressed steel cabinets which are cadmium plated and painted to give a grey metallic hammer finish.



The range has been further reinforced by the production of boards for recessed mounting, illustrated left. They are designed to allow the main body of the board to be sunk into a wall cavity of appropriate depth; the plasterwork and wall finish are then made up to the surrounding surface-plate provided.

Aeroflex ENERGY LIMITING FUSES

Fluvent Cabinet Style Distribution Boards are fitted with Aeroflex Energy Limiting High Breaking Capacity Rewireable Cartridge Fuses to BS.88-1952 Cat. 440 AC5 Class P. Standard fully wired cartridge fuse links are included unless otherwise specified, when appropriate underwirings can be fitted.

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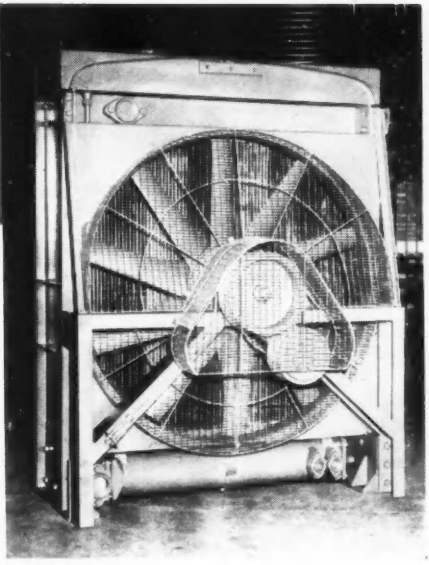
London: 34 VICTORIA STREET, S.W.1.
Glasgow: 5 SOMERSET PLACE, C.3.
Birmingham: 39/41 CARRS LANE, 4.

dm PHS

SERCK

HEAT EXCHANGE EQUIPMENT

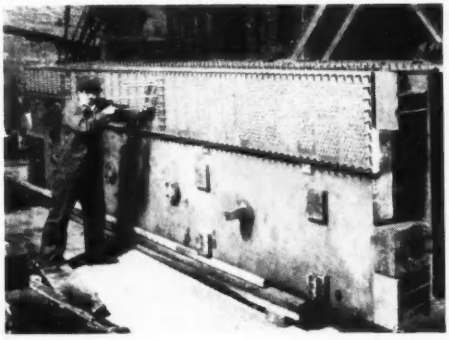


SERCK Combined Radiator and lubricating oil cooler for oil well drilling sets.

SERCK Horizontal type SECTIONAL RADIATOR.

and QUALITY TECHNICAL TUBES for THE OIL INDUSTRY

SERCKALBRA (Aluminium Brass)
SERCKCUNIK (Copper Nickel)
ADMIRALTY BRASS
ALUMINIUM BRONZE
70/30 BRASS



Evaporator for refinery by Procon (Great Britain) Ltd. being tubed with SERCKALBRA Photo by courtesy of Richardson, Westgarth & Co. Ltd.

SERCK RADIATORS LIMITED · SERCK TUBES LIMITED
Warwick Road Birmingham 11 England
MEMBERS OF THE SERCK GROUP

LETTERS TO THE EDITOR

Dear Sir,

THE ECONOMIC PRODUCTION OF HIGH-PRECISION STEEL BALLS

In your issue of December 1959, you summarize an article by H. Gröbner with the above title. I have not had the privilege of studying the original, but it is clear that, in your digest, there is some misconception about the motion of the balls during the grinding process, particularly in connection with your Fig. 4 and the associated text.

It will be seen from Fig. 1a below that, if the top plate *H* is rotated about the axis *X–X*, a turning moment is applied to the ball, causing it to be propelled along the groove. The ball will not slide at its points of contact if it is free to roll, and with this arrangement it is free to roll at *A*, *B*, and *C*, rotating about the moving axis *O-G* (where *O* is the intersection on the *X–X* axis of *BA* produced). As the ball rolls, the points of contact *A*, *B*, and *C* may be traced around the ball, as indicated by dotted lines in the figure.

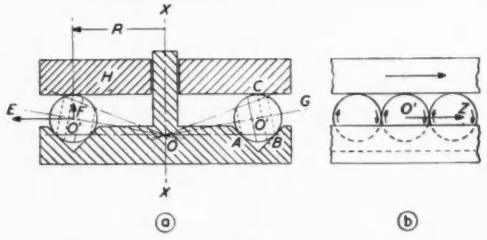


Fig. 1

The rotation of the ball may be represented vectorially as *O'G*, having a horizontal component *O'E* and a vertical component *O'F*. The component *O'E* is a function of the groove radius *R*, while the *O'F* component is a rotation of one revolution for each circuit described by the ball about the principal axis. This is clear from simple geometrical concepts and means that the ball always presents the same side to the centre of rotation, i.e., there is no rotation with respect to the contacts *A* and *B*, as has been implied.

It appears that the only remaining force to induce rotation is the gyroscopic couple acting about the axis *O'Z*, as indicated in the side view in Fig. 1b. In this connection, it can be shown that the gyroscopic torque *T* can be expressed as

$$T = \frac{8\pi\rho}{15\,g}\left(\frac{R/r}{1+\sin\alpha}\right)\left(\frac{\sin\alpha}{1+\sin\alpha}\right)\omega_H{}^2\, r^5$$

where ρ is density, *g* is gravitational acceleration, *R* is the groove radius, *r* is the ball radius, 2α is the groove angle, and ω_H is the angular velocity of the top plate *H*.

If reasonable values of α and (*R*/*r*) are taken, it will be seen that the value of torque *T* at the normal speeds employed is very small and, in fact, can be considered negligible.

The only point at which appreciable sliding takes place is at the point of contact between adjacent balls, where the surfaces are moving in opposite directions (Fig. 1b). Most abrasion will occur at this point, the trace of which around the ball is indicated with a solid line in Fig. 1a.

From this it will be clear that, to rotate the ball indefinitely in this arrangement will not produce a sphere. Your Fig. 5, in fact, shows the key to the process, namely, the recirculating mechanism, which provides for random re-entry of the ball after each circuit in the groove. This explains why the Vee-groove systems which neglect the re-orientating conveyor, as is sometimes done for small batches, are noted for inconsistency, since the essential reorientation has now to be provided by irregularities, vibration, backlash, etc., although to some extent assisted by the gyroscopic couple. It also explains why the process becomes noticeably slower when the grooves are not completely filled with balls.

P. H. Cross

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TRANSLATORS WANTED

Engineering and science graduates with a practical knowledge of Russian and/or other East European languages are invited to apply to the Editor of *The Engineers' Digest* for part-time translating and abstracting of technical articles. As correct English terminology is essential, applicants should include details of their specialized fields of knowledge.

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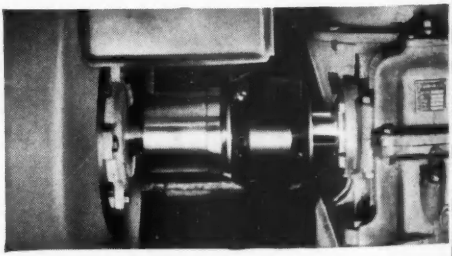

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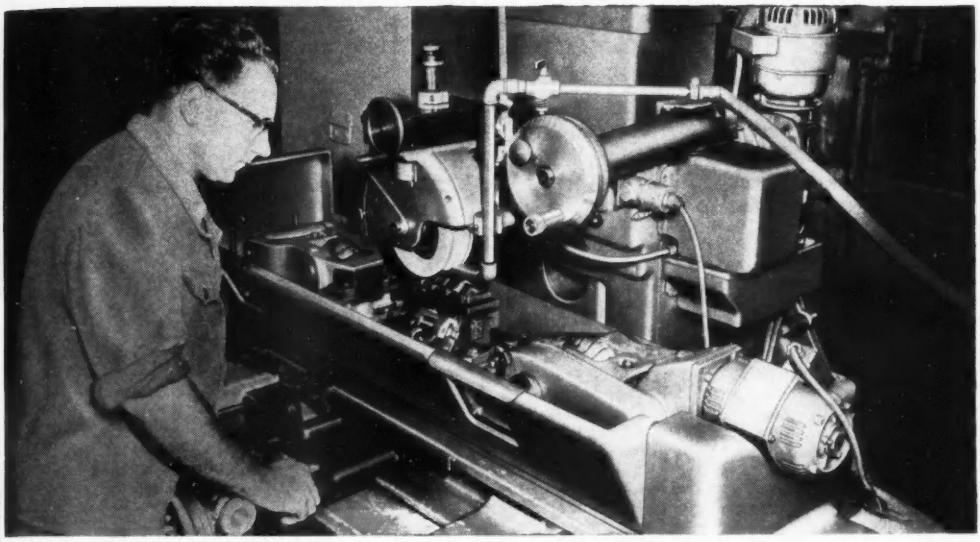

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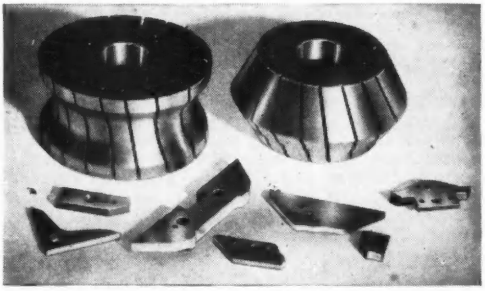

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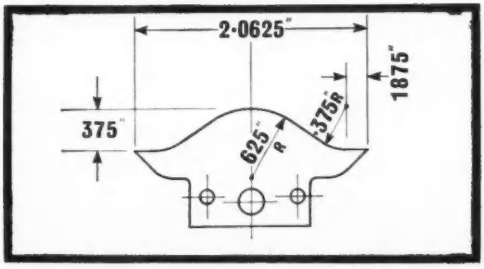

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NEW TECHNICAL BOOK

Cutting Tools, Jigs and Fixtures. By H. C. Town, M.I.Mech.E., M.I.P.E. 247 pp., 227 illustrations. Publishers: Odhams Press Ltd., 96 Long Acre, London, W.C.2. Price: 25/–.

Presenting the latest developments in the field of cutting tools, jigs, and fixtures, this excellent book covers its subject authoritatively and clearly, yet with admirable conciseness. The basic features of tool design, including negative-rake cutting in connection with the use of cemented-carbide tools and the design of cutters for down-cut milling and square-hole drilling, are dealt with in detail, as well as the aspects of heat treatment, tool grinding, cutting speeds, feed rates, and cutting materials, including ceramics and diamond tools. In addition, the economics and design factors of jigs and fixtures are discussed, different machining methods are compared, and a wide range of examples is given of machines and tooling equipment, pneumatic and hydraulic devices, and other types of jigs and fixtures.

Specially worthy of praise are the wealth and quality of the illustrative matter used and the inclusion of a comprehensive set of worked examples of design problems, which will undoubtedly be of practical value not only to students, but also to those engaged in the design of cutting tools in conjunction with jigs and fixtures.

Theory of Mechanical Vibrations. By Kin N. Tong. 360 pp., 101 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 78/–.

Utilizing modern analytical concepts and techniques, and emphasising analytic principles over practical details, this book offers a sound and broad treatment of linear mechanical vibrations and, as such, constitutes an outstanding text and reference work for students carrying out advanced work in applied mechanics.

Professor Tong is to be congratulated on the selection, organization, and presentation of his material, all of which demonstrates the unity and coherence of the theory of mechanical vibration and its connection with other engineering sciences. The book covers systems with a single degree of freedom, systems with two degrees of freedom, systems with several degrees of freedom, and the vibration of elastic bodies, topics receiving special consideration including the principle of superposition, the eigen-value problem in matrix, differential and integral equations, and energy methods. In addition, systematic and logical developments of all the important theorems and results are given.

The Other Side of the Moon. Translated from the Russian by J. B. Sykes. 40 pp., 8 illustrations. Publishers: Pergamon Press Ltd., Headington Hill Hall, Oxford. Price: 10/6.

On October 4, 1959, a space rocket was successfully launched in the Soviet Union with the specific object of resolving certain problems in the study of outer space and more particularly to obtain photographs of that surface of the moon which cannot be observed directly from the earth. While it is true that the wealth of information obtained from this launching is still under study, and that a scientific publication which includes comprehensive descriptions of the features of the other side of the moon and the method of determining their nature will shortly be issued, the U.S.S.R. Academy of Sciences presents for the first time in this little book the results of the preliminary study of the photographs made by equipment in the space rocket.

Essentially, the space rocket is an automatic interplanetary station equipped with complex radio, electronic, photographic, television, and other apparatus, as well as with a special orientation system, devices for the programmed operation of the apparatus installed, an automatic temperature-control system, and power supplies. Details of the station and its orbit are given, together with the methods used for photography and image transmission, and reproductions of the three now-famous photographs of the other side of the moon.

Of undeniable topical interest and commemorating, as it does, an achievement which only a few short years ago would have been ridiculed as impossible, this interesting book is recommended to all those who now realize that the conquest of space is no longer an extravagant fantasy but a practical concept which will almost assuredly come to fruition in our own lifetime.

Statics of Soil Media. 2nd edition, 1960. By V. V. Sokolovski. Translated from the Russian by D. H. Jones and A. N. Schofield. 250 pp., 200 illustrations. Publishers: Butterworths Scientific Publications, 4 & 5 Bell Yard, London, W.C.2.

Though Professor Sokolovski's work in the field of plasticity is well known to research workers, this English translation renders his work accessible to a wider readership and enables engineers to become acquainted with current theoretical research in problems of plastic failure. A large number of the mathematical problems encountered in the analysis of the stability of foundations and slopes, and in the design of embankments and fills can be treated by purely statical considerations, and the book is devoted to an examination of these problems.

This new and completely revised edition, which is based on the original 2nd edition published in Moscow in 1954, also incorporates certain revisions and amendments provided for the English translation by the author, as well as a series of new problems investigated since the appearance of the first edition.

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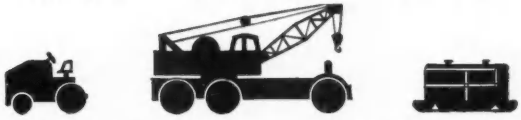

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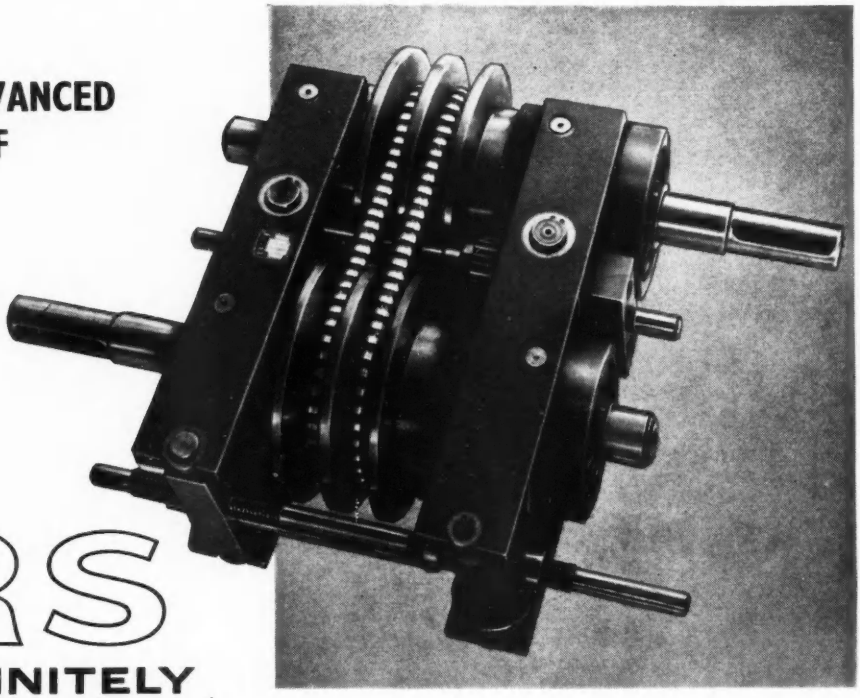

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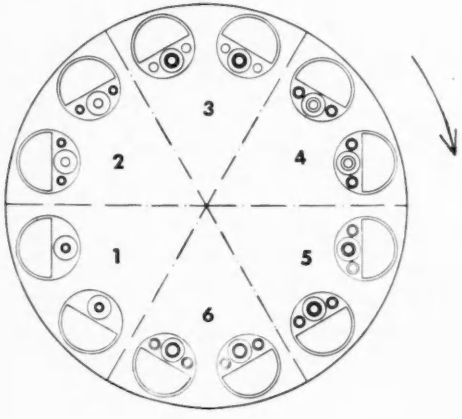

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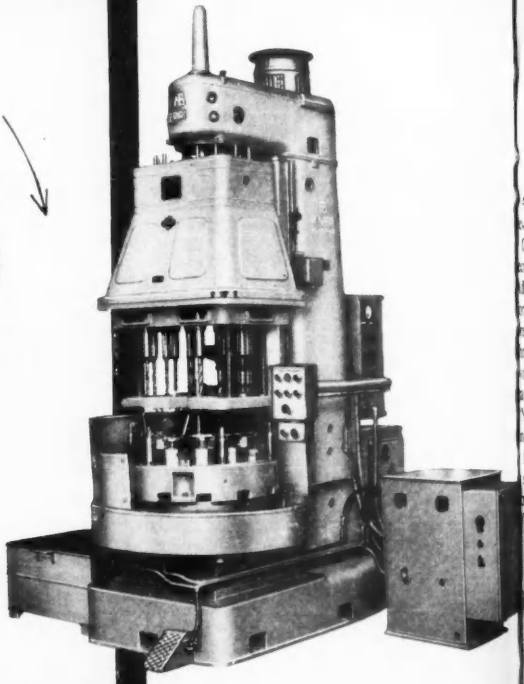

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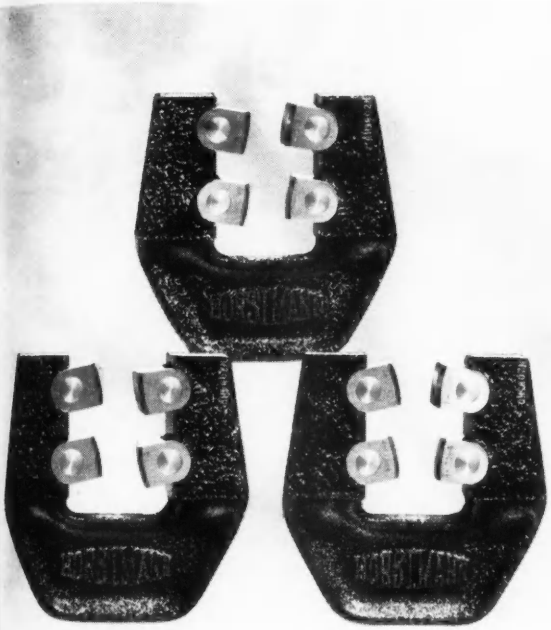

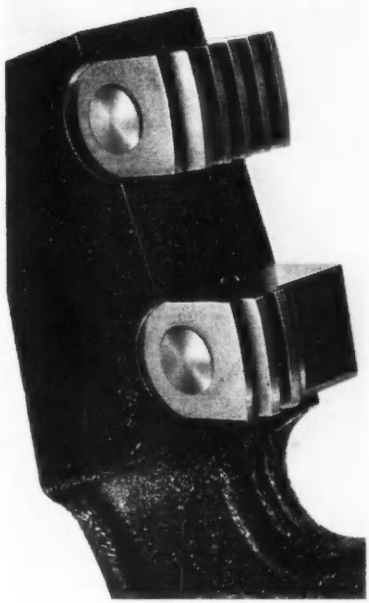

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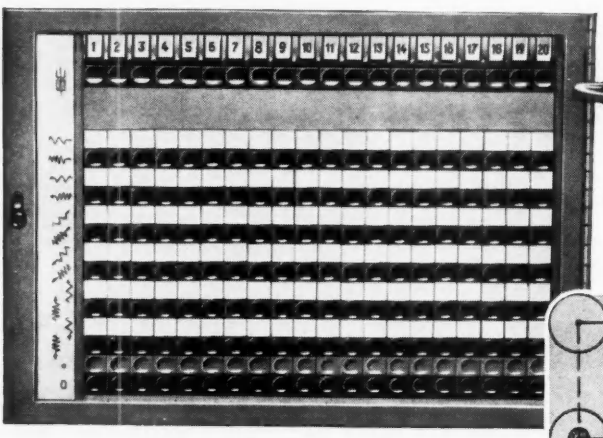
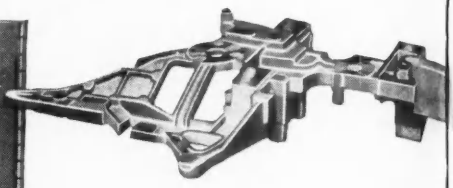
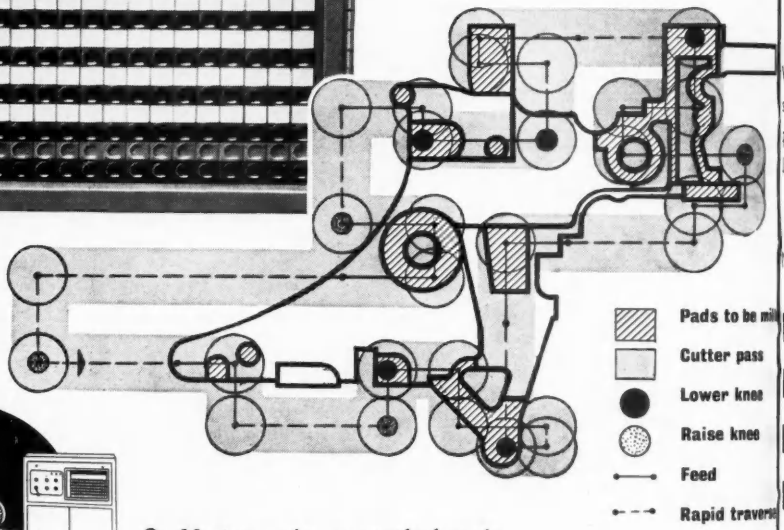
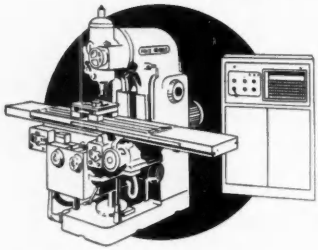






Cutter pass and rise-and-fall motions of the knee during automatic 3-dimensional programme milling of the workpiece shown above right.



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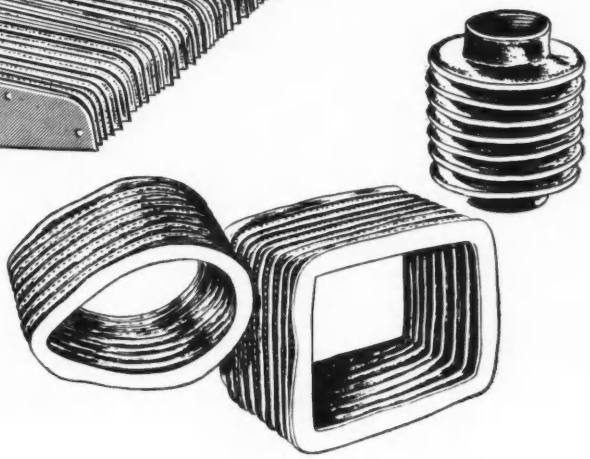

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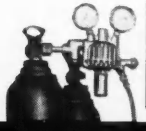

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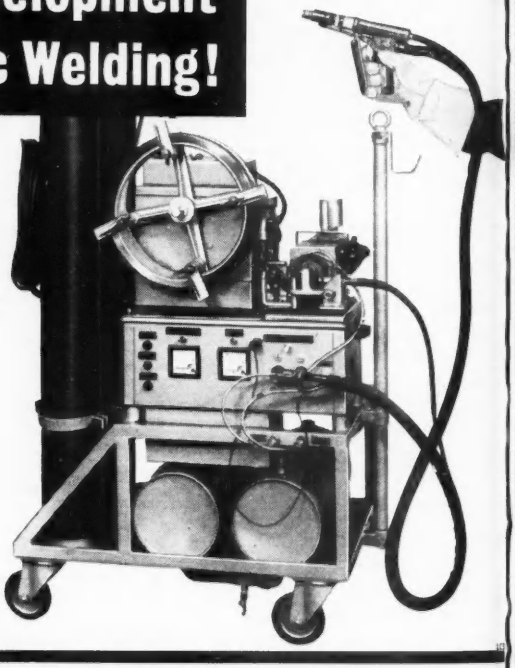

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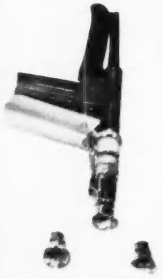
Spot, Plug and Tack Welding Nozzles (1 nozzle shown fitted to standard Hand Gun).



Type C.P.L. Timing Unit for Spot, Plug and Tack Welding.

Occupying less than 6 sq. ft. of floor space, this compact unit offers these great features :

★ Completely self-contained. The Lincoln-Cloos C.A.3 Welding Unit incorporates its own re-circulating water cooling system and gas bottle support.

★ Highly efficient modern design Hand Gun—can be used for both semi-automatic seam and spot welding.

★ The special type C.P.L. timing unit and nozzles for Spot, Plug and Tack Welding (illustrated) can be easily fitted in a matter of minutes.

★ Infinitely variable wire drive unit.

★ Wire feed rolls adjustable to suit wires of varying diameters.

All these *extra* features plus the other advantages of CO_2 Shielded-Arc Welding—rapid metal deposition, practically no formation of slag, excellent results in positional welding—are available to you when you buy the LINCOLN-CLOOS type C.A.3 Shielded-Arc CO_2 Semi-Automatic Welding Unit—the machine with the added PLUS of ***FULL SPOT AND TACK WELDING FACILITIES.*** Write today for further details to:

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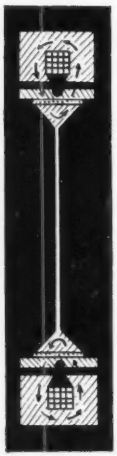

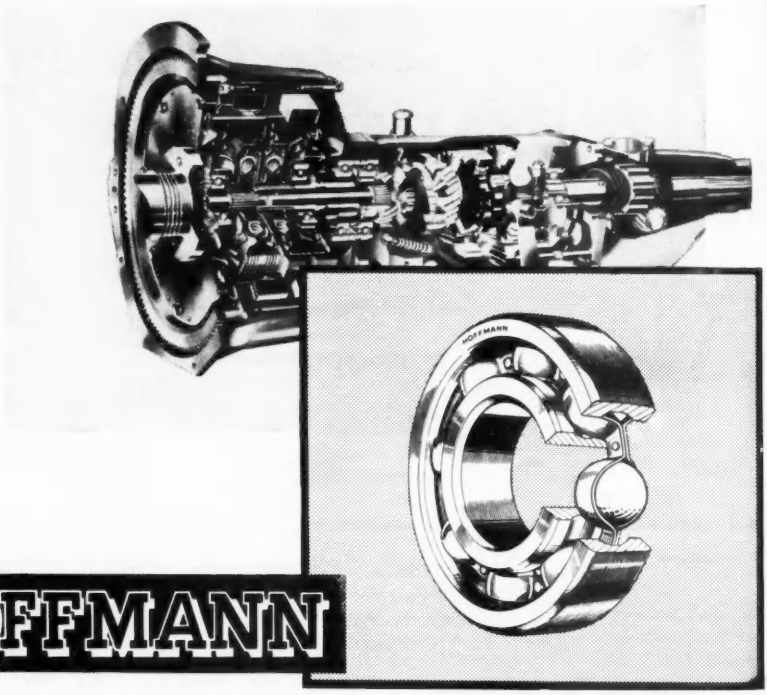

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Smiths fully automatic transmission makes use of a layshaft type gearbox but, by the clever application of two magnetic powder couplings and an electro-mechanical control system, gives fully automatic gear changing and elimination of the clutch pedal.

Hoffmann Ball Bearings are fitted in this transmission and contribute much to the smoothness and efficiency of the whole system.

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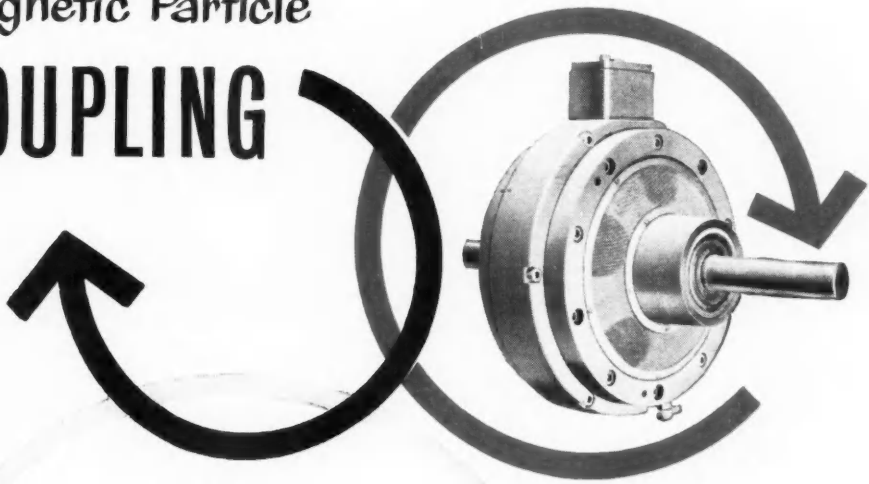
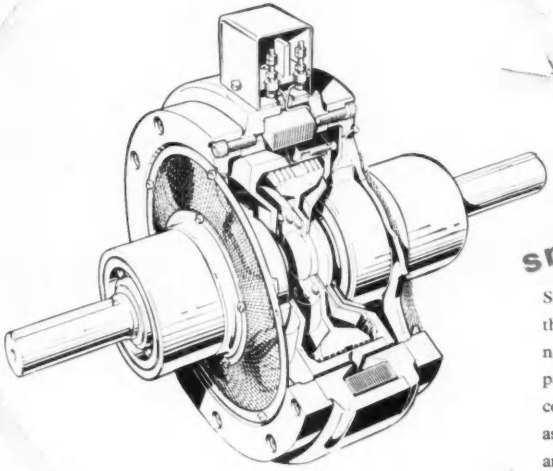
COUPLING





smooth yet positive

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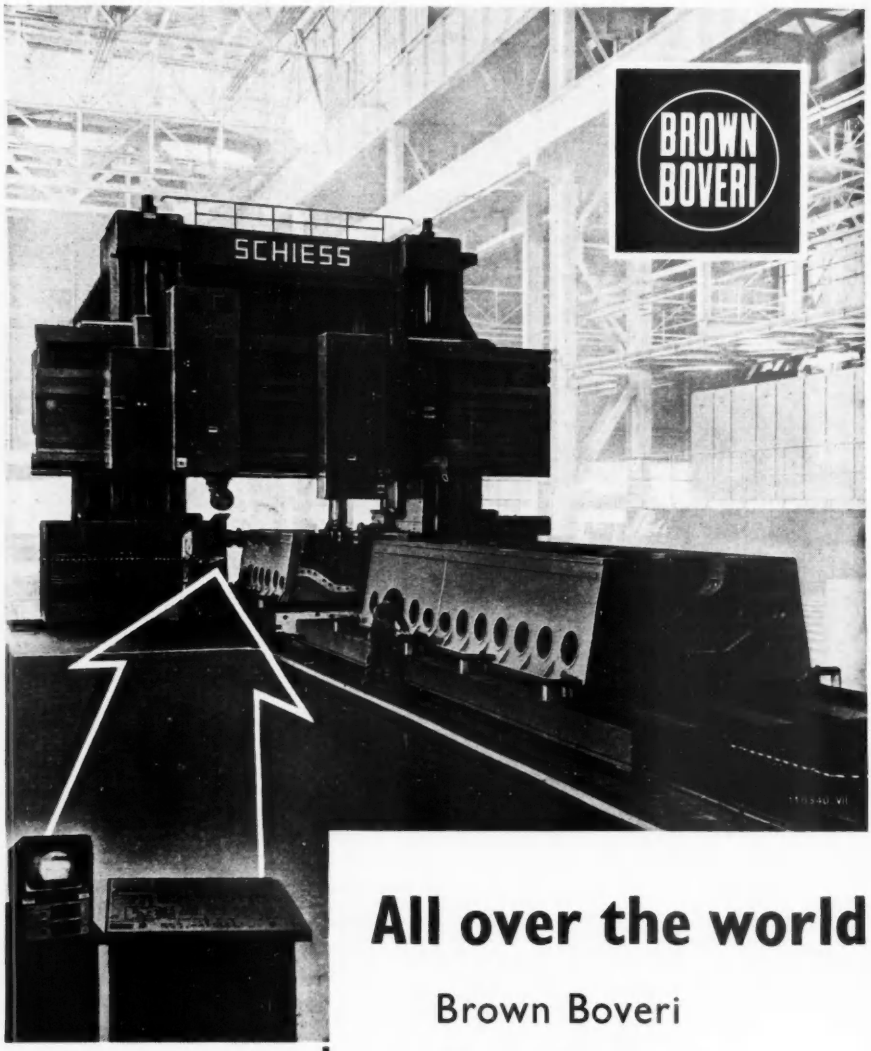

This large milling machine weighing 900t and with a frame 46m long stands in the workshops of Sulzer Bros., Winterthur, Switzerland, and is the largest of its kind in the world. It contains 140 electric motors with a total input rating of about 1100 kW all of which were supplied by Brown Boveri.
The novel design of the control desk (inset) with a coloured mimic diagram allows the machine to be controlled with ease, despite the large number of drives.

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for Machine Tools

from the extremely simple to
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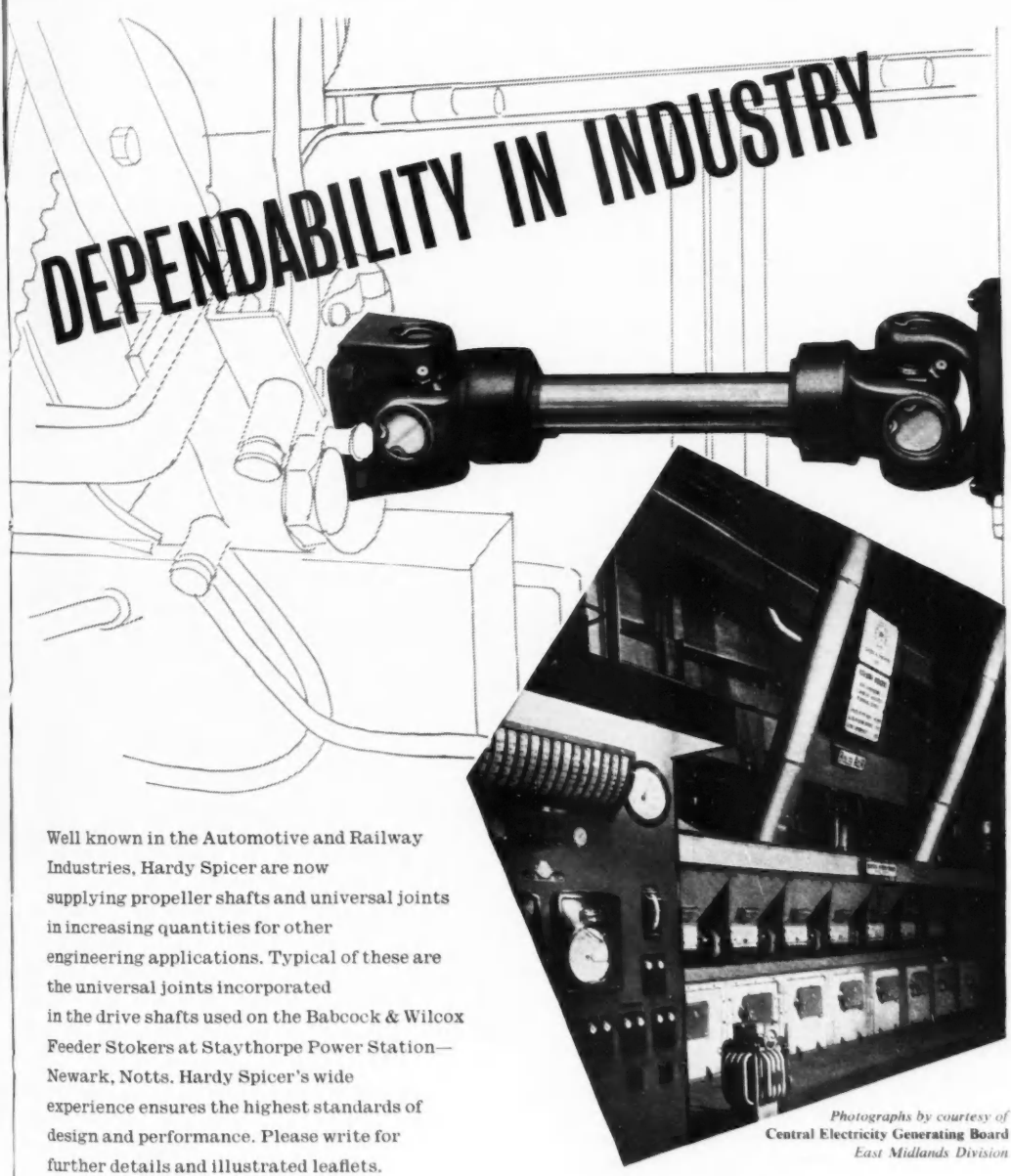

Well known in the Automotive and Railway Industries, Hardy Spicer are now supplying propeller shafts and universal joints in increasing quantities for other engineering applications. Typical of these are the universal joints incorporated in the drive shafts used on the Babcock & Wilcox Feeder Stokers at Staythorpe Power Station—Newark, Notts. Hardy Spicer's wide experience ensures the highest standards of design and performance. Please write for further details and illustrated leaflets.

Photographs by courtesy of
Central Electricity Generating Board
East Midlands Division

HARDY SPICER

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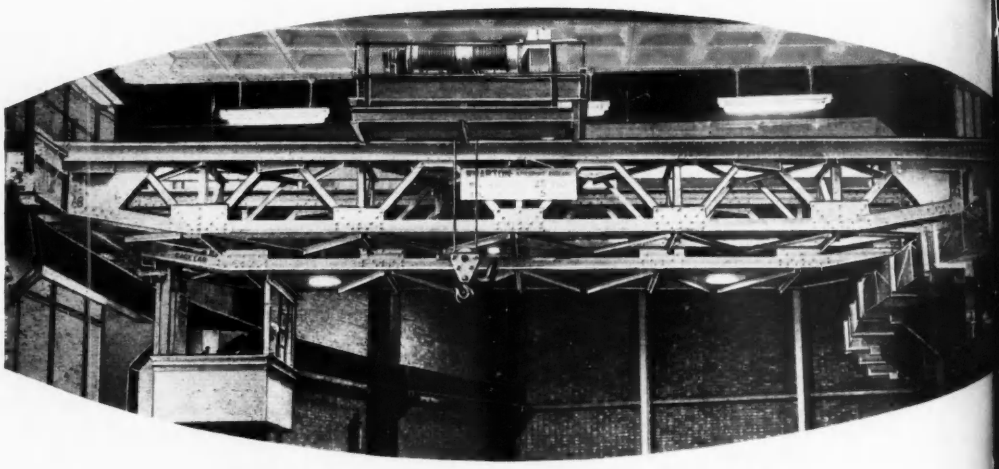

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The advent of nuclear engineering made demands upon the Crane industry for special design and methods of operation not previously necessary. Wharton have met this challenge by supplying specially designed cranes to many nuclear projects, one of which, illustrated on this page, was supplied to the Berkeley Atomic Power Station.

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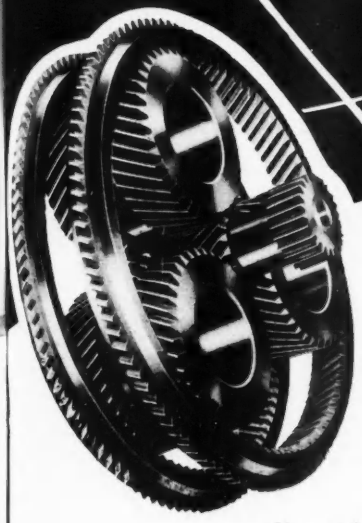

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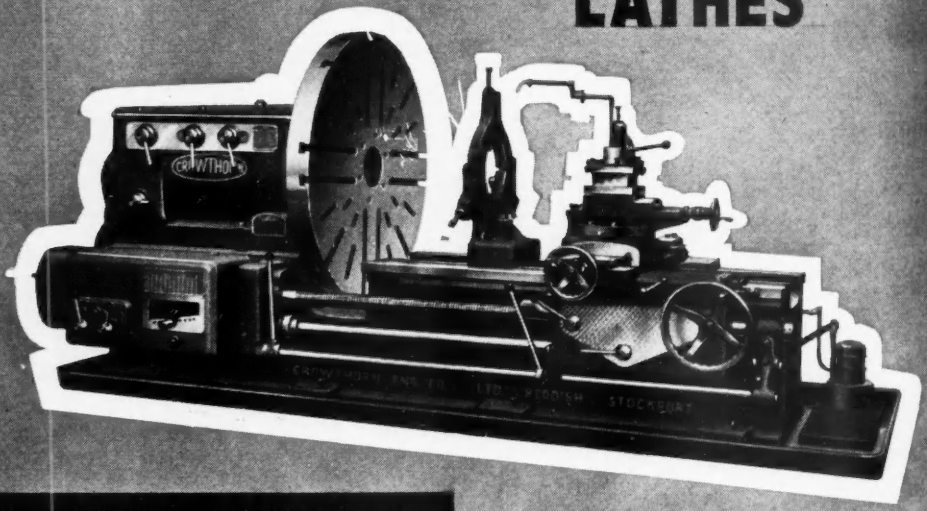

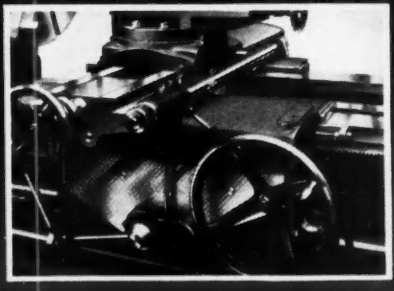

The illustrations are of a Crowthorn 36 in. swing Boring and Facing Lathe with, inset, detail of the automatic feed trip mechanism.

Features include:

1. Heavy design for rigidity and accuracy.
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3. Tailstock available if required.
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Facilities are provided for selecting one of up to ten tools and for controlling a large number of other variables such as tool feed rates, feed depths and spindle speeds.

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No electronic valves used.

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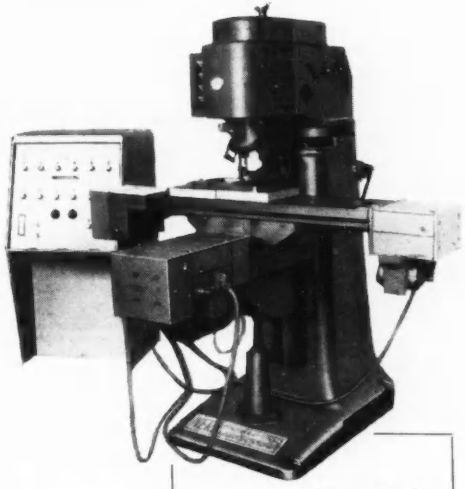
CUTS OUT ERRORS
Autoset is highly accurate—automatic compensation is provided for table backlash and cumulative lead screw errors.

CUTS THE COST
A complete equipment for automatic control in two dimensions including tape punch costs only £1,500. Manual control considerably less.

Descriptive leaflet No. 186 *sent on request*



Autoset fitted to Vero Auto-drill, 6 spindle Turret Head—32" × 9" table. Spindle speeds 300-6000 r.p.m.— ⅛ drill capacity. Full details available from Catmur Machine Tool Corpn. Ltd., 103 Lancaster Road, London, W.11.

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The Steadfast Flexible High Speed hacksaw blade is hardened on the teeth only by a new technique, giving cutting performance equal to the normal "all hard" high speed blade. At the same time it imparts a flexibility which enables the blade to be used by the unskilled, without fear of breakage.

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For economy and efficiency, there is none better than the Steadfast Flexible High Speed blade.

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12"	½"	·025"	14, 18, 24, 32

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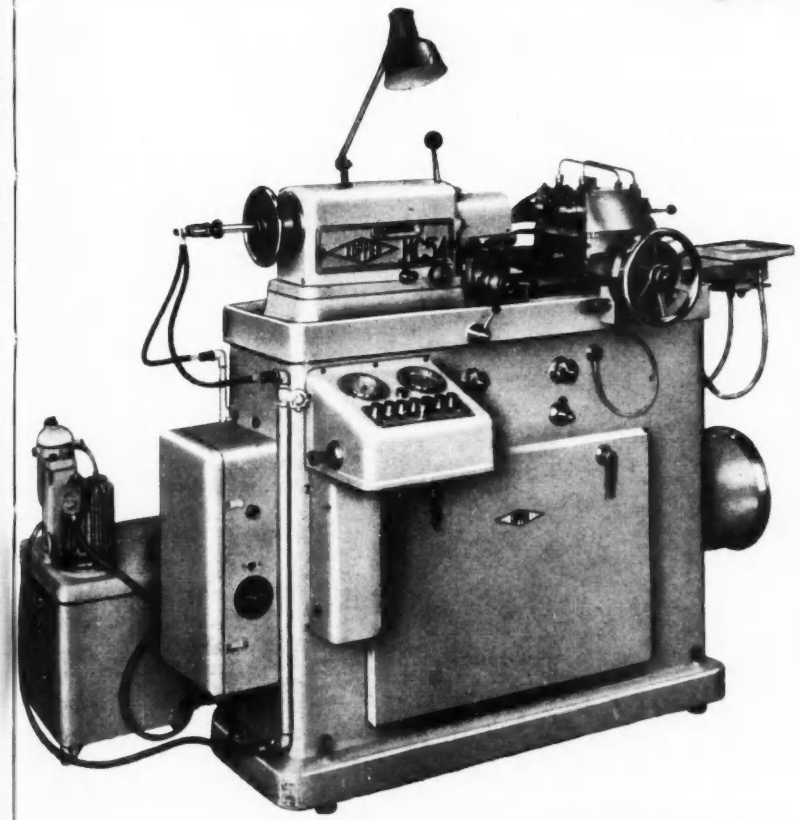

TECHNICAL CHARACTERISTICS

Internal grinder for holes of 1 to 20 mm diameter in high-hardness alloys, e.g., gauges, dies, etc. Spindle speeds from 60,000 to 140,000 rpm.— Quick adjustment for control of diameters, with automatic feed of the spindle head: automatic stop — Supply voltage according to requirements. Weight of complete Grinder approx. 750 kg.

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Grinder specially designed for the mass production of injectors of any type for the internal grinding of gauges and dies in tungsten, carbide and other alloys, for work requiring a very high degree of precision of the order of 0·0003 mm both in roundness and centricity with surface micro-roughness of 0·00025 mm. Perfectly smooth surfaces are obtained, in view of the complete absence of harmful vibrations the perfect finish of the surfaces, combined with exact geometrical shape, is always assured by the M.C.54 Grinder fitted with patented M.C.52 "Turbo Spindles", with automatic take-up of bearing play, oil-mist lubrication, and other features introduced into its construction. All the adjustments of the individual members of the machine are hydraulically controlled. The machine is fitted with turbine-driven spindles of very high rotational speeds, from a minimum of 60,000 to a maximum of 140,000 rpm; one of these spindles serves to grind cylindrical parts and the other conical parts (e.g. injector and valve seats) according to requirements.

The rotating spindle unit of the M.C.52 "Turbo Spindles" employ a small turbine and the hydraulic system adopted, as compared with electrically-driven spindles, affords numerous advantages, including the following :—

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- variable speed range between the limits required, depending upon the internal dimensions to be ground.
- normal operating speed : 120,000 — 130,000 rpm.
- speed variation between full and no load about 3-4 per cent.
- extremely simple automatic lubrication, without the need for cooling equipment.
- possibility of grinding diameters from 1 to 20 mm.
- automatic take-up of bearing play by means of a patented device which guarantees longer life to the bearings.
- operating life of the spindle at least 800 working hours guaranteed.
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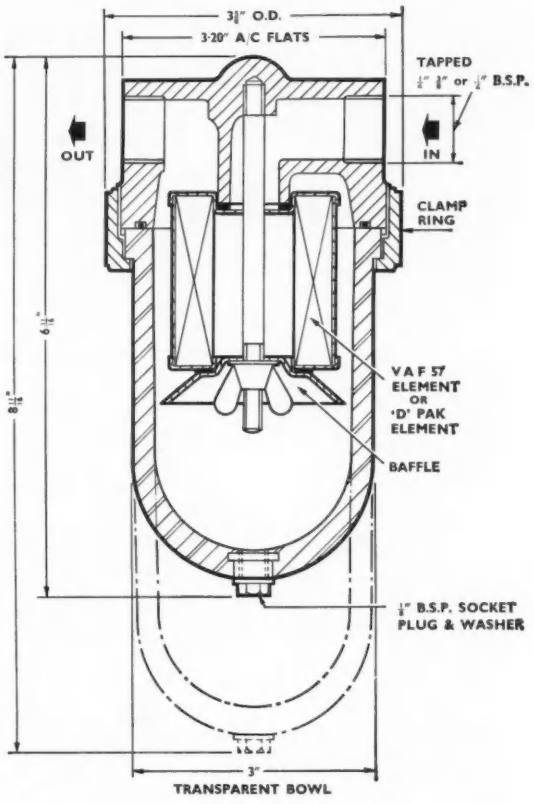
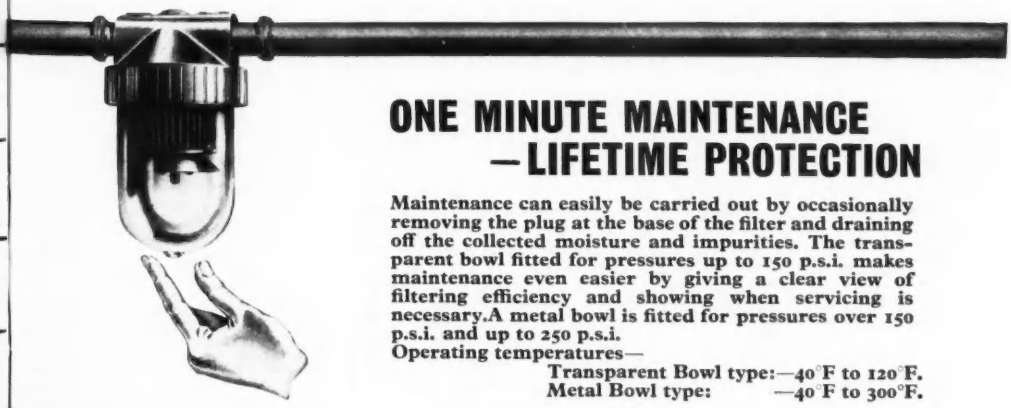
ther types of element are available for special plications and full details of these may be tained from our technical sales department.





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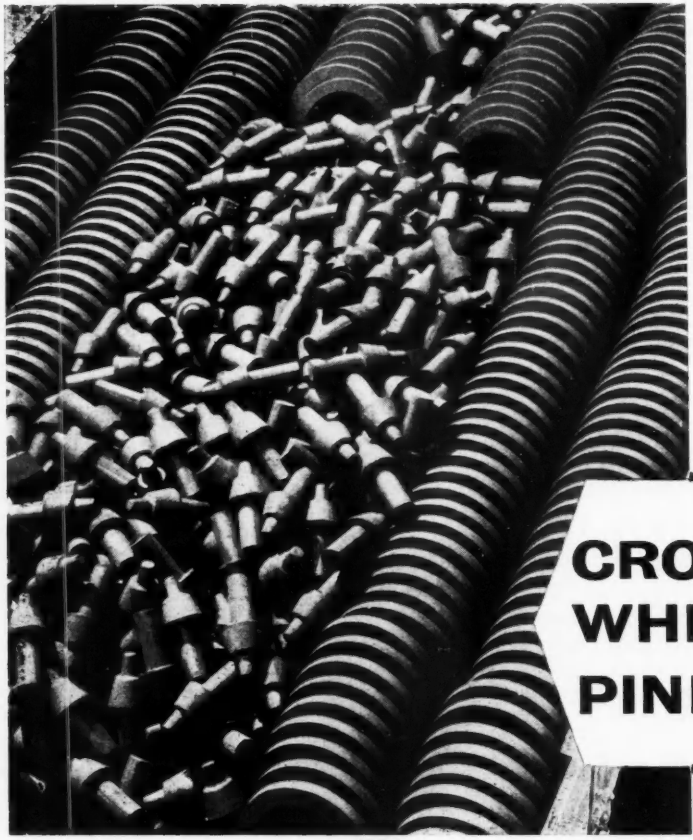

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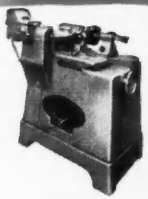
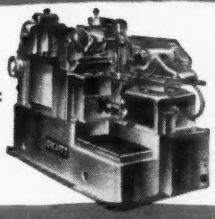
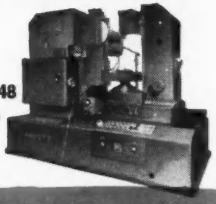


Orcutt Lead Measuring Machine

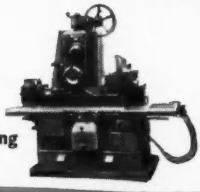
Orcutt Automatic Gear Grinding Machine



Orcutt GC 48 Spur Tooth Grinding Machine



Orcutt 20" & 36" Hydraulic Shaft Grinding Machine

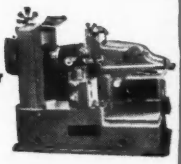


STANDS

The Gear Grinding Co. Ltd.

210-211

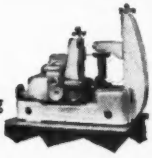
Orcutt H. M. Internal Gear Grinding Machine



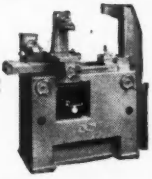
No less than six new machines designed and manufactured by The Gear Grinding Co., Ltd., make their debut on Stands 210 and 211.

Competent technical personnel staff the stand throughout the exhibition and an office for confidential meetings is available on the gallery.

Orcutt Involute Measuring Machine Mk III



Orcutt Involute Measuring Machine Mk IV



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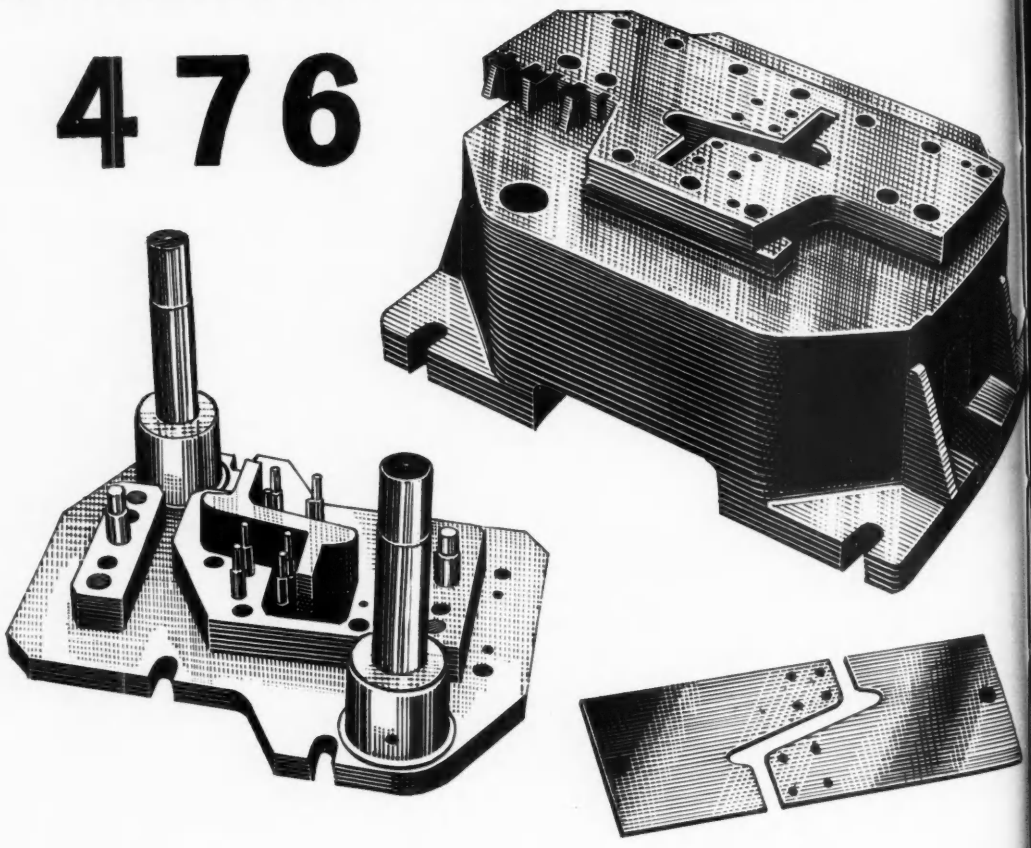
SANDERSON tool steels

476



'476' Heavy duty die steel of the high carbon, high chromium type, has outstanding wear-resistance but is tough and machinable. It is particularly recommended for tools operating under conditions of severe wear and abrasion and where maximum runs are required.

The above illustrations show a punch and die set produced from '476' steel by The Mining Engineering Co. Limited, Worcester.

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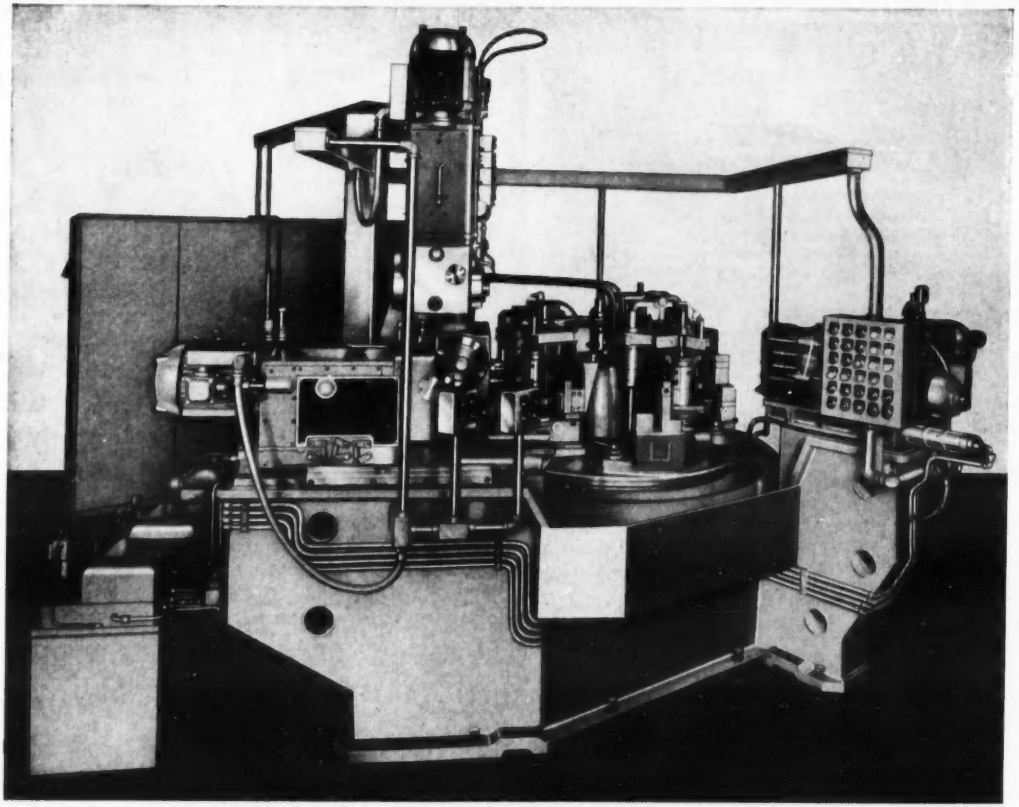

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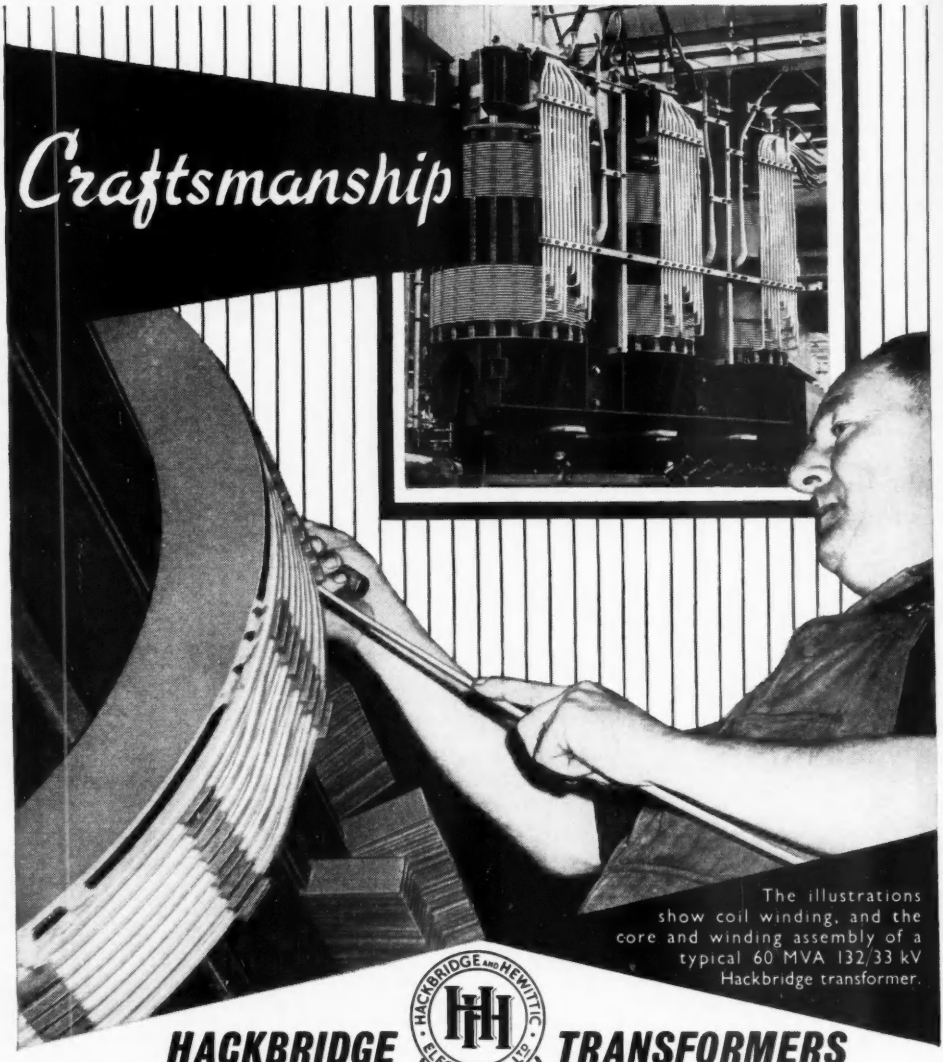

The illustrations show coil winding, and the core and winding assembly of a typical 60 MVA 132/33 kV Hackbridge transformer.

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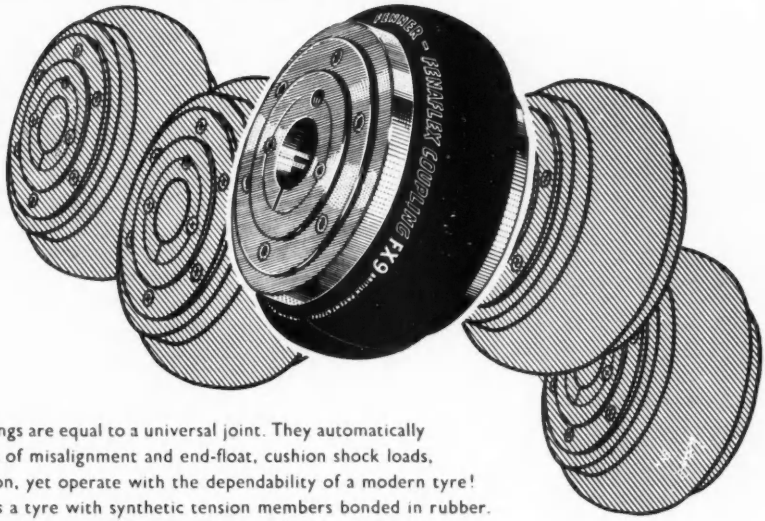

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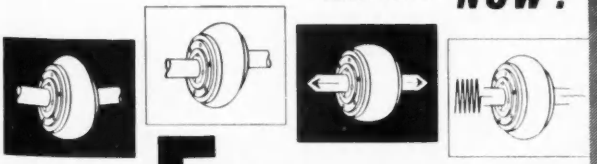

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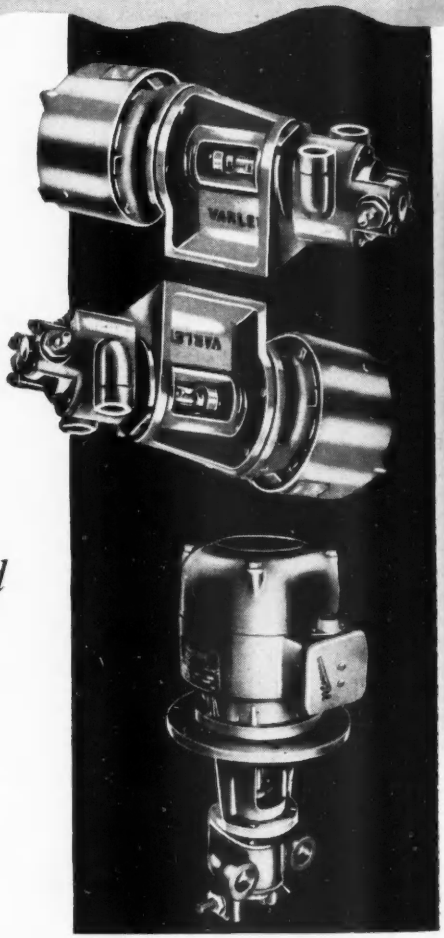

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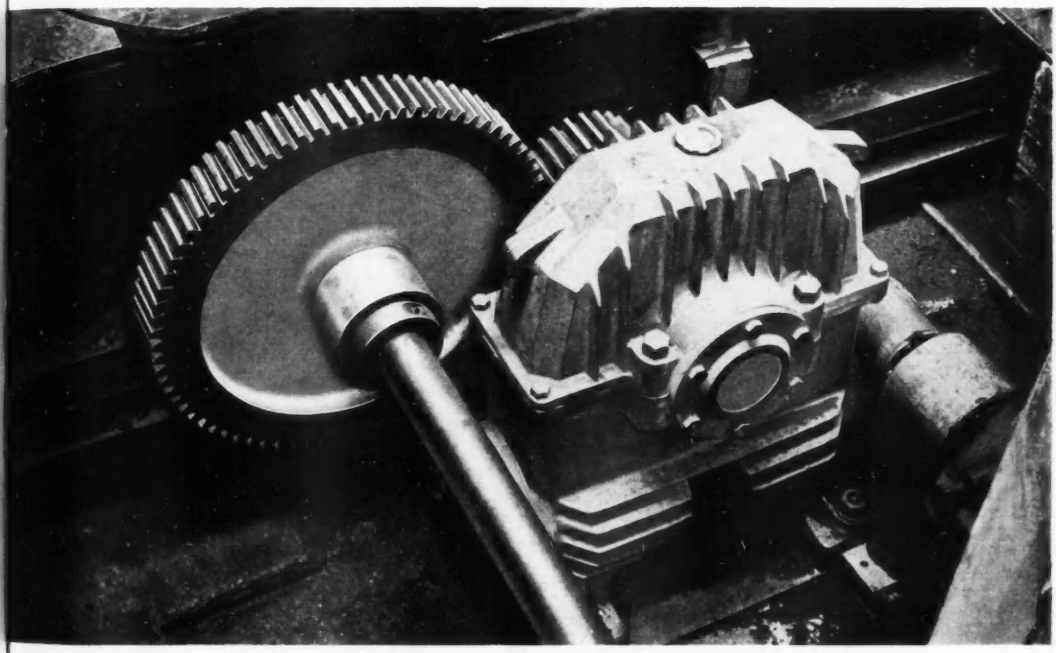

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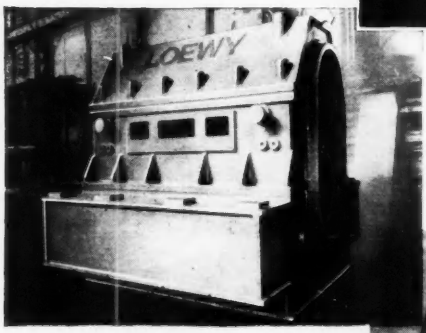

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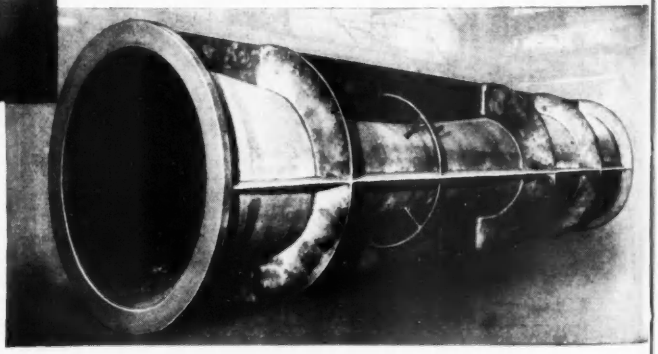

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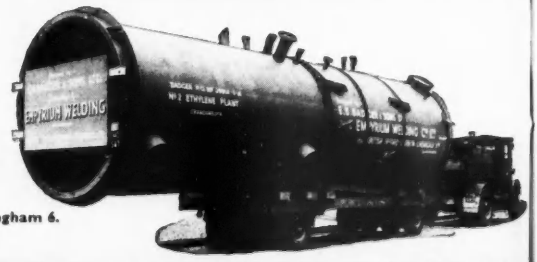

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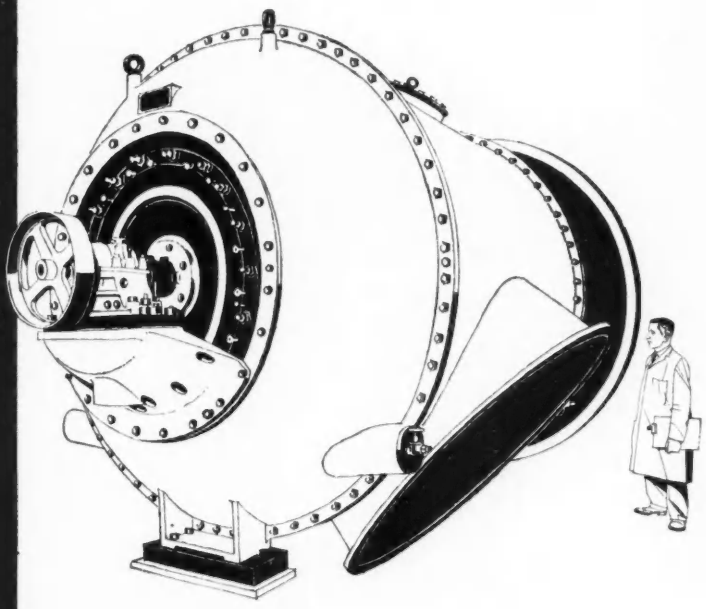

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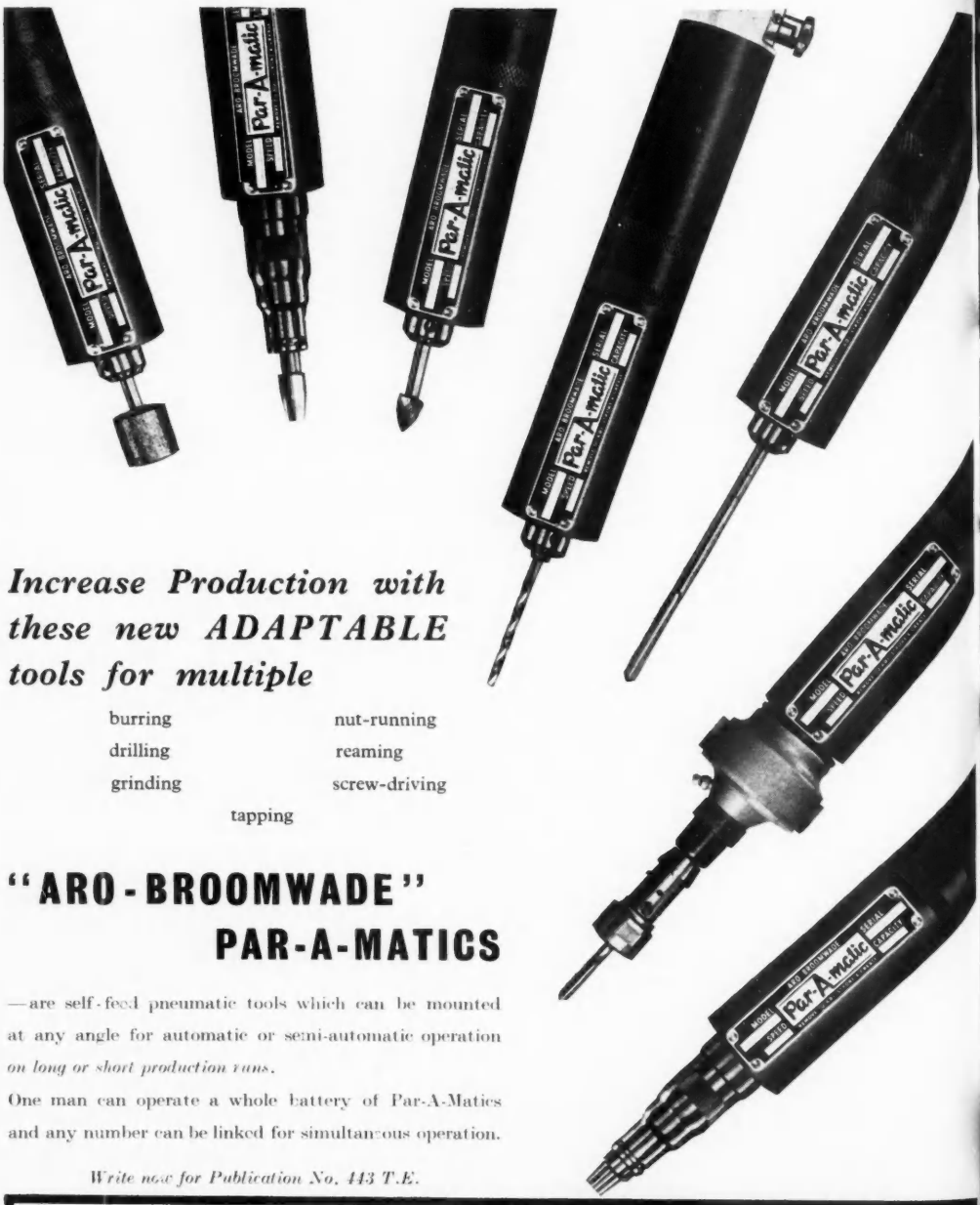

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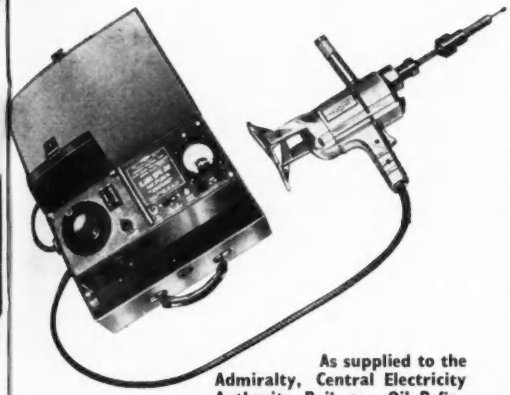

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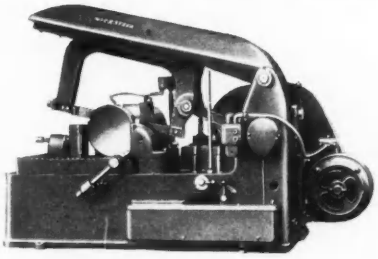

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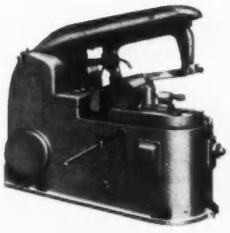

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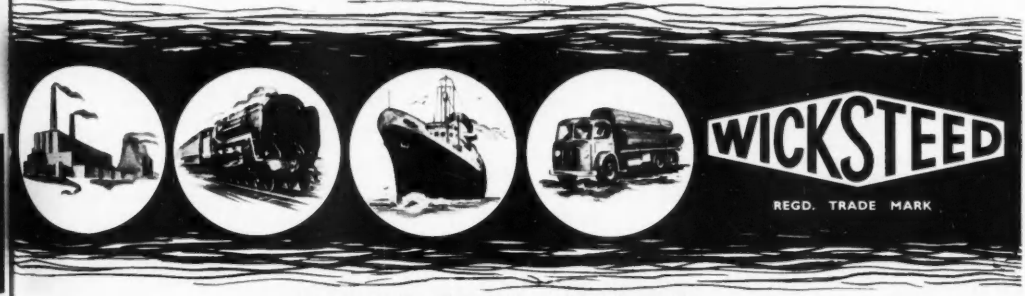

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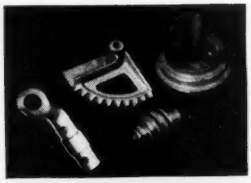

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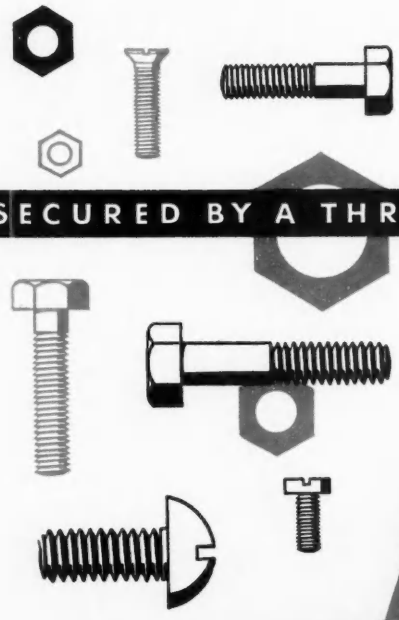

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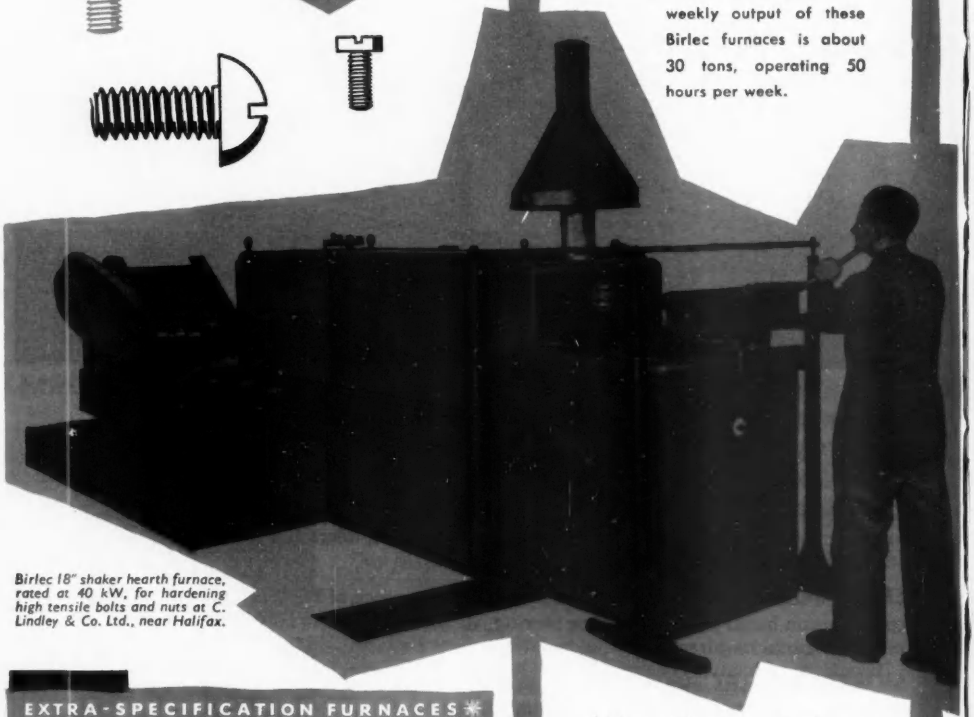

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *PRESSURIZATION OF GRANULAR SOLID FUELS*

One of the main problems which faces the designer of a solid-fuel system for a pressure-fired device is that of introducing the pulverized or granulated particles into the combustion space against the system pressure, by far the most convenient method being to employ a solid-fuel pump designed to act in a manner similar to that of a liquid pump. The prime need is to pressurize the fuel particles or, more accurately, to pressurize the air in the case of a fuel-air mixture, or the water in the case of a slurry in which the fuel is entrained. Until recently, no such pressurizer was required, and very little work was done on the pumping of solids; however, the advent of the newly developed coal-burning processes in combustion and gasification at elevated pressures has provided a stimulus to research in this direction, these processes including the coal-fired gas turbine, the pressure-fired boiler for the steam-gas cycle, and pressure gasification.

In a recent paper, different methods of pressurizing solid fuels are reviewed and the characteristics of presurizers discussed in relation to power loss due to venting the pressurizing air, the wear of surfaces in contact with the solids, and effective sealing. It has been found that power loss due to air venting cannot be totally eliminated and that the simple lock hopper is the most suitable device in existence to-day, owing to its lower capital and maintenance costs, smaller power loss, and greater reliability.

From *Transactions of the ASME, Series A*, U.S.A., April 1960, pp. 156–168.

• *PROBLEMS OF TWO-PHASE FLOW*

Many difficulties arise in the treatment of heat-transfer problems in which liquids and gases flow together in the same tube. It is now reported, however, that experiments have provided solutions to a number of problems involved in two-phase flow, and film thickness and other pertinent flow characteristics can be predicted from a knowledge of the system. This research has primarily been directed to the investigation of annular two-phase flow in horizontal tubing, the liquid completely surrounding the gas as a film clinging to the inside of the tube, tests being conducted by feeding compressed air into long, clear plastic tubes of 1, 2, or 3 in. diameter. A mixer, with a 0·015-in. wide annular slot, feeds a uniform film of liquid into the air stream, the liquid usually being either water or a glycerine-water solution which can be varied in viscosity. While the film thickness varies around the tube, owing to the tendency of the force of gravity to pull the liquid towards the bottom, variations in film thickness around the tube are not as noticeable with the viscous glycerine solutions.

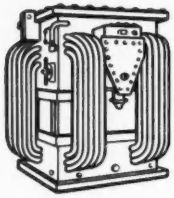
It was found that the liquid gained energy from the gas when travelling along the tube and that, as the liquid increased its velocity, the film became thinner and less eccentric. Thicker film areas offer a rougher surface to the gas flow than thinner films, so that the top surface, where the film is thinner, offers less resistance to flow than the film surface at the bottom of the tube. Thus, the gas velocity profile is affected by the surface film, and this change in the velocity profile is believed to be partially responsible for the large pressure drops encountered in tubes with two-phase flow.

From *The Cornell Engineer*, U.S.A., March 1960, page 29.

• *NATURE OF THE PHENOMENON OF MAGNETIC ANNEALING*

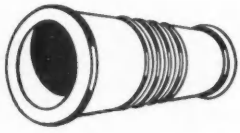
For many years, it has been known that, if soft magnetic alloys of nickel-iron or nickel-cobalt-iron are heat-treated in a strong magnetic field, their magnetic moments will tend to align to produce a magnetically oriented material, this tendency arising from a uniaxial magnetic anisotropy introduced by the field heat treatment. The origin of this uniaxial anisotropy, however, has not been satisfactorily understood, and the theoretical basis for magnetic-field annealing has been debated for some time, though the generally accepted theory is based on short-range ordering of the metal atoms.

Recent research now indicates that magnetic polarization does not result when these alloys are heat-treated in a magnetic field, unless about 14 ppm of oxygen are present in the alloy. With a lower oxygen content, the annealed alloys do not respond, and no uniaxial anisotropy is developed. At oxygen contents between 14 and 20 ppm, there is apparently little variation in the strength of the anisotropy. Although there appears to be little appreciable change in the magnetic response for reasonable increases above this level, substantially greater amounts of



from transformers

to bellows



the relief of stresses demands

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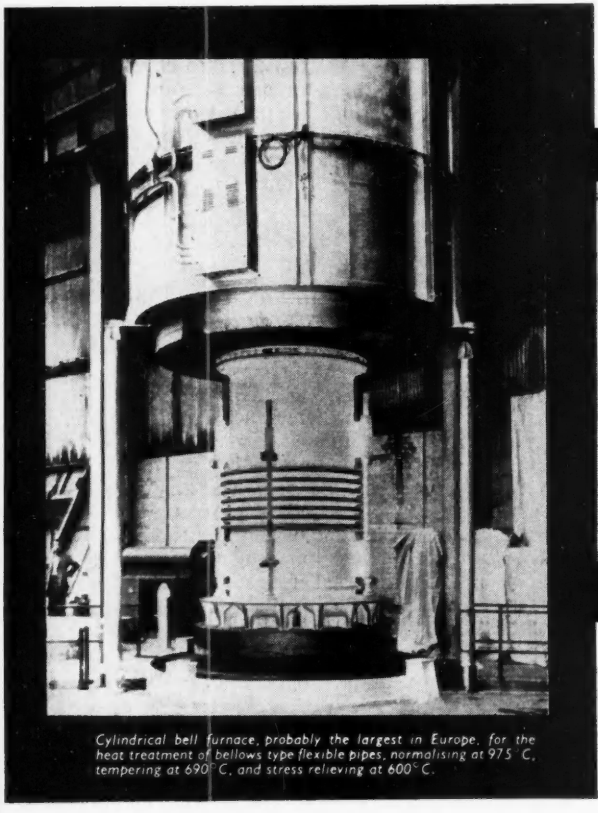
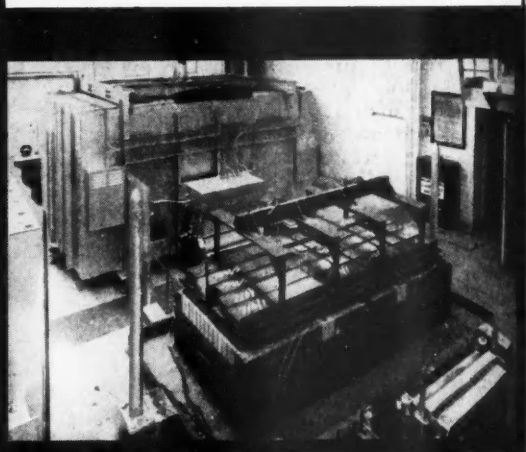


Cylindrical bell furnace, probably the largest in Europe, for the heat treatment of bellows type flexible pipes, normalising at 975° C, tempering at 690° C, and stress relieving at 600° C.



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oxygen may result in the formation of oxides of the constituent metals. While the mechanism by which oxygen causes this effect is not yet fully understood, a theory to account for it is that the oxygen atoms deposit on the stacking plane of the crystal at certain elevated temperatures, resulting in a displacement or dislocation of the next plane of atoms. When enough of these oxygen atoms are present, the alloy can be magnetically oriented by field heat treatment.

From *News from Bell Telephone Laboratories*, U.S.A., March 1960.

● *DESIGN OF LAVAL NOZZLES FOR HIGH-SPEED FLOW*

As is well known, it is necessary to use a well-designed Laval nozzle in order to obtain uniform supersonic flow in a wind tunnel, the shape of the nozzle usually being determined by a method in which a start is made with initial data, sonic or supersonic, as given at a section of the nozzle, and continuation downstream is generally carried out by successive construction of a net of Mach waves or characteristic curves. The flow is first accelerated by suitable expansion through the diverging part of the nozzle until it attains the desired Mach number on the axis, followed by a region with a simple wave field in which the nozzle wall is designed to reflect no wave. After passing through this region, the flow becomes uniform with a given Mach number. The shape of the wall portion for no reflection has already been tabulated in previous work for the special case of sharp corner expansion. Alternatively, by starting from radial supersonic flow (source flow), the shape of the portion of the wall designed for zero wave reflection can be expressed by an analytical formula established by Foelsch.

In either case, however, the subsonic inlet of the nozzle which should lead to the starting condition assumed in this method is generally designed by less accurate methods or is sometimes determined empirically. It is therefore the purpose of a recent Japanese paper to derive an analytical solution for the nozzle flow of practical interest, utilizing the equation of Tomokita and Tamada for nozzle flow, and to establish the flow pattern at the subsonic inlet of a Laval nozzle. Tomokita and Tamada have based their analysis on the assumption of approximate isentropic flow; in the present paper, however, the author has assumed the gas to obey the exact isentropic law. A number of streamlines in the subsonic and transonic region is computed, each of which may be taken as representing the wall of the nozzle when carrying out its design.

From *Trans. Japan Society for Aeronautical and Space Sciences*, No. 3, 1959, pp. 77–82.

● *ELECTRICAL REDUCING PROCESS FOR METAL ORES*

A recently patented process is intended to solve the problem of substantially reducing the time per charge in the electrical reduction of ores, particularly iron ores, and also to develop a furnace which is suitable for the highest possible throughput rates. In this process, a bed of fine-grained coal is heated by means of an electric current passed through the bed, the greater part of which is maintained in suspension by the gases formed during the reaction. In this way, a quasi-liquid or fluidized turbulent bed is produced, into which fine-grained ore is fed, the grain size varying from 0·1 to 0·5 mm. The reducing coal forms a bed with a depth of several metres in a shaft of appropriate size. The current-supply electrodes are mounted so as to project at the periphery of the shaft into the fluidized bed, the voltage for heating the bed amounting to several thousand volts, depending on its degree of fineness and density.

The reduction process is carried out by sprinkling small-grained iron ore on to the layer of heated coal in such a way that the forming of compact portions of ore in the coal bed is avoided, i.e., each particle of ore is surrounded by an excess of coal. Owing to the difference in specific gravity, the ore particles sink downwards into the quasi-liquid or fluidized bed of coal, collecting underneath at the bottom of the reduction vessel. On their travel through the coal bed, the ore particles are reduced, some by the reducing gases and some by direct contact with the coal particles.

From *Brit. Pat. Spec.* 827,205.
Werner Wenzel, Bad Godesberg, Germany.

● *PRODUCTION OF GERMANIUM AND SILICON p-n JUNCTIONS BY EVAPORATION*

It is extremely difficult to prepare by conventional methods *p-n* junctions with uniformly large areas and minimum alloying thicknesses, as required for photocells and other photoelectric applications. It is now reported, however, that germanium and silicon *p-n* junctions with high photoelectric characteristics have been successfully produced experimentally in Japan by means of an evaporation method, in which the alloying element arrives at the semi-conductor in an "atom-by-atom" manner, thereby achieving intimate contact and making it possible to exercise close control over the geometrical shape of the junction.

Initially, experiments with the evaporation method were conducted with indium, which was evaporated onto a suitable *n*-type germanium crystal preheated to 530°C, but it was found that this method, though superior to conventional methods of producing *p-n* junctions, was not completely satisfactory, owing to the fact that

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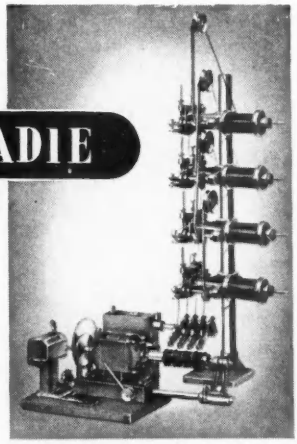

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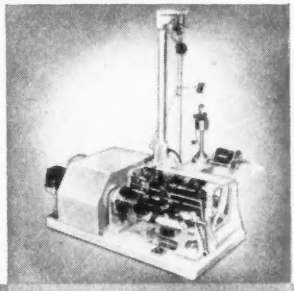

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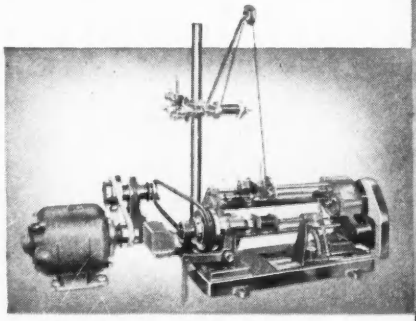

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the deposition of indium was not entirely uniform and the area of the junction was thus reduced appreciably. Subsequently, gallium was used in place of indium, because its surface tension is lower and its distribution coefficient on germanium higher, making it possible to produce a uniform layer on the germanium crystal. Evaporation of the gallium was carried out under various conditions, and it was found that the most important parameter for producing good photoelectric characteristics is the alloying temperature. With an alloying temperature of 500°C, junctions with good photoelectric characteristics were formed, the regrowth layer of these junctions usually being extremely flat and uniformly distributed, and of very small thickness.

This evaporation method has also been applied in the preparation of silicon junctions, optimum results being achieved with aluminium evaporated onto a silicon crystal preheated to between 700° and 800°C. In this case, the saturation current was found to be considerably lower than that of germanium junctions, making these silicon junctions not only suitable as photocell elements, but also for use in photodiodes and photoresistors.

From *The Journal of the Institution of Electrical Engineers of Japan*, January 1960, pp. 43–50.

● *NON-DESTRUCTIVE TEST FOR INCLUSIONS AND PORES IN METALS AND PLATINGS*

A new non-destructive test method for ionic surface inclusions in metals and for pores through an electro-plate or cladding, is based on the electrode-potential difference existing between dissimilar ionic materials when immersed in a suitable electrolyte. The so-called "local" or galvanic action taking place in the vicinity of an inclusion or pore produces an electrical field, provided that the inclusion and matrix materials, or cladding and base materials, will pass into ionic form in the electrolyte and that the two reactions do not produce equal potential differences. Because of this action and the relatively low electrical conductivity of the electrolyte, a measurable potential field is maintained in the electrolyte over a relatively large volume, compared with the dimensions of the inclusion or pinhole.

This field can be detected by means of a voltage-sensitive device connected between the test sample and an electrode or probe in the vicinity of the inclusion or pinhole and which contacts the electrolyte. In many cases it is convenient to construct the probe of the same material as the test specimen, so that, in areas with no exposed foreign material, a zero potential is obtained. This technique is not, however, essential, since the constant potential difference produced by a test specimen and a probe of a different material in no way hinders an observable change in the potential when an inclusion or pinhole is encountered. The method naturally depends on the prerequisite that the reactions of the materials involved with the chosen electrolyte lie at different levels in the electromotive series.

From *Nondestructive Testing*, U.S.A., March/April 1960, pp. 99–102.

● *FLAT WELDING WIRE*

An investigation into the physical aspects of flat welding wire, as compared with round wire, has been based on observation of the arc formed when a flat knife-blade switch or circuit-breaker is operated. The apparently flat arc which ensues encouraged speculation as to how this flat arc would behave if continuous as a welding arc. For the purpose of this investigation round welding wire was flattened by cold-rolling and its welding characteristics observed. A width-to-thickness ratio of 3 : 1 appears to be the most favourable, and it was found that, when used for welding under the same welding conditions as the equivalent round wire, the flattened wire has marked directional characteristics. With the width parallel to the direction of travel of the welding head, great penetration is achieved, while, with the width perpendicular to the travel, a very wide flat bead can be laid down, though still excellently fusing with the base metal.

A large flat wire of equivalent area can be substituted for two round wires used in tandem, obviating the need to synchronize the feed of round wires. Electrical contact along the whole width is far superior to that of the small arc of contact of a round wire, while the slit nozzle used to hold the flat wire rigidly prevents the wire from spiralling or casting, as is often the case with round wire. Furthermore, the metal deposited is uniformly dense and free from porosity. Nozzles or welding heads and feed rolls can readily be converted or adjusted to handle flat welding wire, which can be produced at a cost approximately 15% higher than round-wire of equivalent cross-sectional area. However, this additional cost is insignificant and is, in any case, more than offset by the flexibility and wide variety of bead obtainable.

From *Welding Journal*, U.S.A., April 1960, pp. 348–350.

● *MECHANICS OF THE SHEET-BENDING PROCESS*

Sheet bending is a fabricating process in which initially flat sheets are permanently deformed into intricate shapes by the use of plate rolls or dies, the sheet being subject to a complex history of loading intimately related to the fabricating process. When the load-application device is released, the sheet tends to return to its initial shape—a phenomenon called

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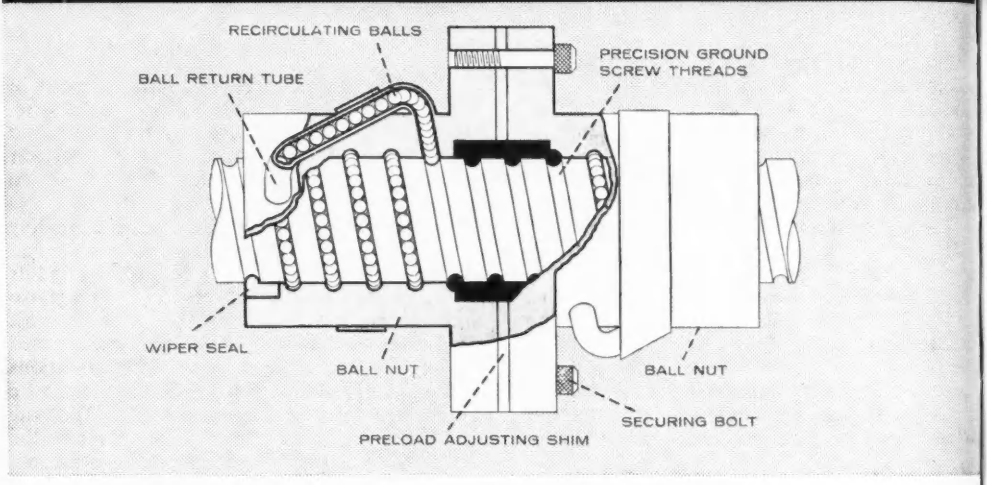

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springback. Springback must therefore be taken into consideration by deforming the sheet initially to an extent beyond that which is finally required, this extent usually being determined from experience or experimental data. It has been found that a completely elastic residual-stress state does not occur in sheet bending, in contrast to the conditions observed in most other plastic-flow analyses.

This phenomenon may be ascribed to the fact that, in sheet bending, the neutral surface during plastic loading is at a position which is different from that which it occupies during the elastic unloading process. The portion of the sheet between the two positions of the neutral surface is subject to stresses which are of the same algebraic sign during loading and unloading, thus causing the persistence of a residual plastic region in the interior of the sheet. The relative size of the plastic zone decreases as the ratio of curvature to thickness of the sheet increases and, by analysis, two sets of expressions are obtained for residual stresses and deformations. One of these sets applies to sheets whose concave surfaces have radii of curvature under load which are greater than 0·84 times the sheet thickness and is associated with a residual plastic zone in the sheet; the other set of expressions applies when the ratio is less than 0·84 and is associated with residual plastic zones near the concave boundary of the sheet.

From *Trans. ASME, Journal of Applied Mechanics*, U.S.A., March 1960, pp. 34–40.

● *EFFECTS OF AIR ON THE HIGH-TEMPERATURE FATIGUE OF CARBON STEELS*

Corrosion by environment has severe effects on the fatigue strength of materials at high temperatures. Since, at room temperature, corrosion-resistant materials such as stainless steel have a lower fatigue strength in air than in a vacuum, the fatigue strength of these materials at elevated temperatures may also be affected by air at these temperatures. It is therefore possible to consider the usual *S-N* curves relating to high-temperature fatigue in air as consisting of two parts, i.e., real high-temperature fatigue and corrosion fatigue.

As a first step in the study of atmospheric effects on fatigue strength, a Japanese report is concerned with comparative fatigue tests on carbon steels carried out in air and in town gas at 550°C in order to reduce air oxidation, under rotating bending and also under repeated torsion. As a result, it was found that, in the case of long lives and low stresses, the fatigue strength was higher in town gas than in air. However, the fatigue strength was lower in town gas than in air in the case of short lives under high stresses; in other words, the *S-N* curves in air and gas cross each other. This may be attributed to hydrogen embrittlement produced by nascent hydrogen generated by the high-temperature steel/steam reaction from the water vapour of the combustion gases. The *S-N* curve at elevated temperatures may therefore have a considerably different shape if the effects of air oxidation are removed.

From *Bulletin of the Japan Society of Mechanical Engineers*, February 1960, pp. 76–80.

● *IMPROVING THE STRUCTURE OF ALLOYS BY IRRADIATION*

According to a recently patented process, it has been found that the structure of metals and alloys may be controlled by irradiation with from 1×10^8 to 4×10^8 roentgens/gm, leading to negative ion formation. Thus, the packing of metallic atoms can be changed either to increased solubility, increased ductility, lower melting point with looser molecular arrangement, or, on the other hand, to increased hardness, brittleness, higher melting point, and very close molecular packing, the difference in the two functions depending on the valence induced by the irradiation. For instance, it has been found that by such irradiation of metal powder and by subjecting the powder to pressures of 25,000 to 50,000 psi, followed by sintering, a greater degree of compactness is attained, owing to the greater degree of metallic binding.

Particularly in the transition elements the "d" electron configuration plays a very important role. Thus, in powder metallurgy, by irradiating the powder prior to compression and sintering, the resulting addition of electrons creates a condition of cohesion closely related to alloying. The electron concentration, i.e., the number of valence electrons per atom is therefore the controlling factor in the new process. Different metals, such as copper and aluminium which are difficult to join, can, when subjected to irradiation, be made to unite more readily under compression in the cold state when two smooth surfaces are brought into apposition with each other. Also, by irradiation it is possible to promote the rate of alloying between metals that are normally difficult to alloy, examples being the alloying of lanthanum and caesium with iron, and iron with vanadium.

From *Brit. Pat. Spec.* 832,484.
Union Carbide Corporation, New York, U.S.A.

Readers desiring further information on any developments reported in THE BLUE PAGES are invited to write to the Editor. Copies of the full specifications of any British patents mentioned, which are published by courtesy of H.M. Stationery Office, should be obtained from the Patent Office, 25 Southampton Buildings, Chancery Lane, London, W.C.2. Price 3s. 6d. each.

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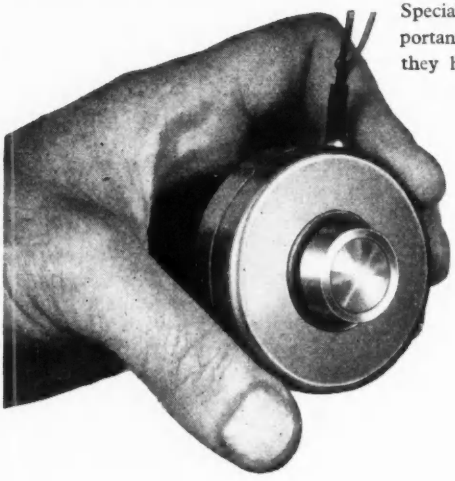

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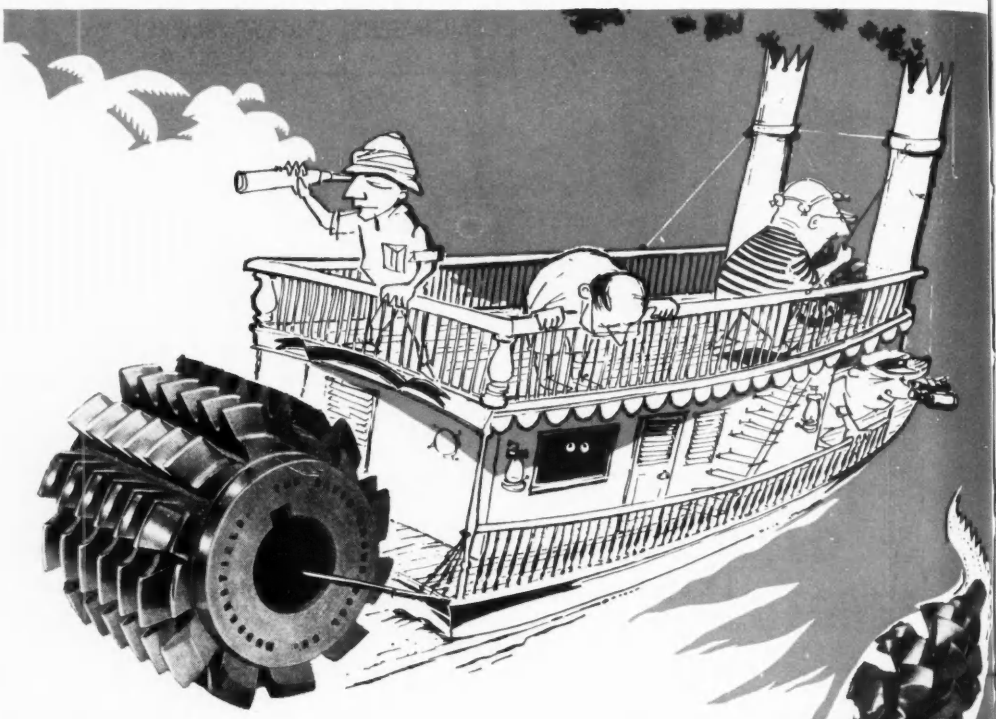

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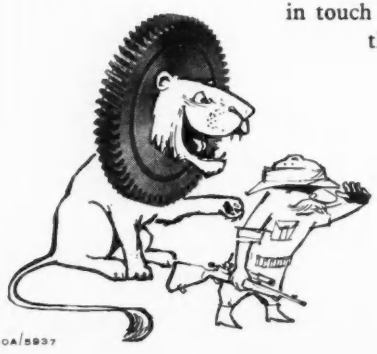

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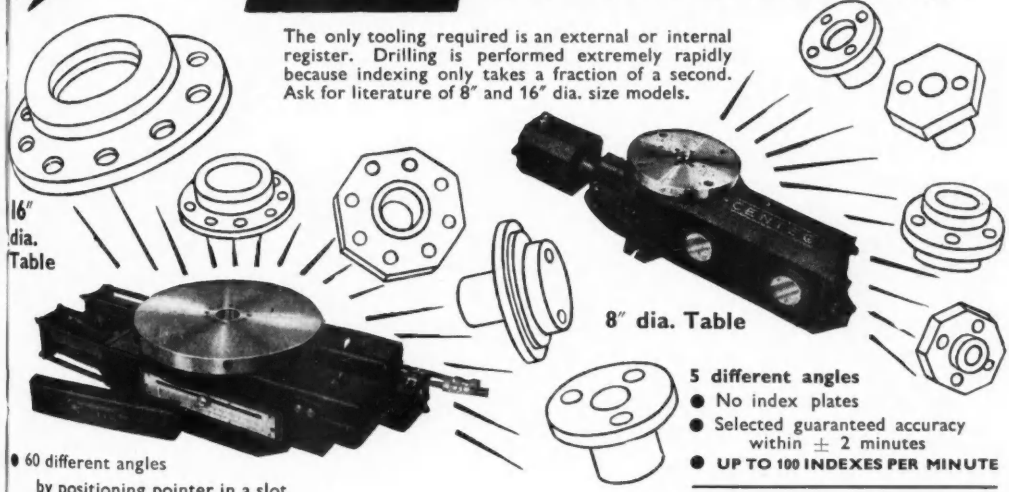

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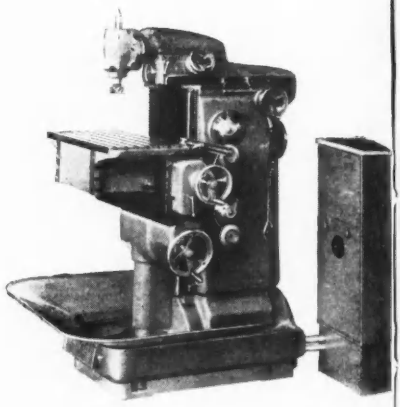

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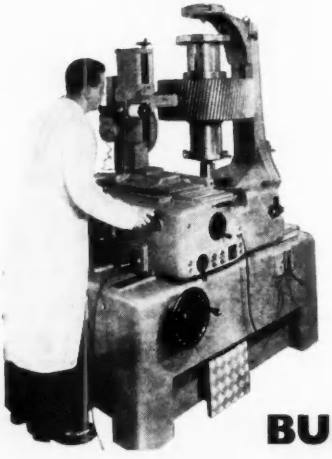

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Programme-Controlled Machine Tools

By R. C. BREWER*

THE aims of automatic operation of machine tools are, in general, fairly clear and reasonably well accepted. In times of rising labour rates, one aim certainly is to reduce production costs, but the extent to which any particular kind of automatic operation may be successful is governed very much by the level of production; for example, the elaborate cylinder-block transfer line of the popular-car producer (which may be considered as partial automation) is of no economic use to the company which produces a few hundred luxury cars a month, inasmuch as, to such a company, a numerically controlled jig borer may be far more useful.

Automatic operation is more likely to be successful as a means of reducing the number of operators required; thus, eight centre lathes would require eight skilled operators, whereas eight single-spindle automatic screwing machines could be tended by one skilled setter and a feeder under almost all conditions. It might be argued that this advantage is not strictly due to automatic operation, inasmuch as a centre lathe on power feed is effectively automatic in operation, but rather to the fact that the automatic screwing machine will run without the attention of the operator for a sufficiently long period to enable him to deal with other machines.

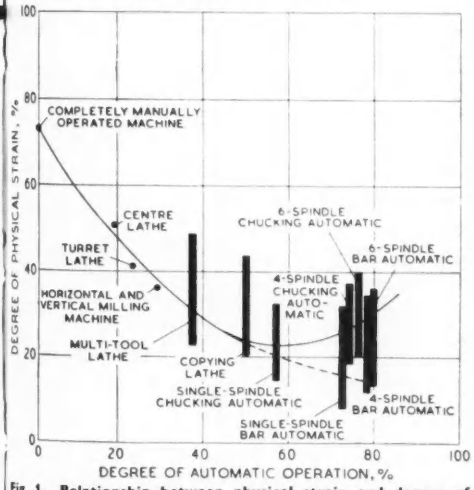

Fig. 1. Relationship between physical strain and degree of automatic operation.

With an increase in the degree of automatic operation, a reduction in physical and mental strain is certainly achieved when only one machine is tended. If, however, an operator is assigned to more machines because the time he has to devote to each decreases with an increase in the degree of automatic operation, then the strain he undergoes may actually begin to increase when the degree of automatic operation increases beyond a certain point. This is illustrated in Figs. 1 and 2, which show respectively degree of physical and mental strain as a function of degree of automatic operation, and which have been plotted from figures given by Moll and Ulbricht†. It will be seen from these graphs that, beyond a degree of automatic operation of about 40%, there is a progressive decrease in both physical and mental strain if only one machine is tended, as shown by the dotted lines in Figs. 1 and 2, whereas the curve begins to rise in both cases (solid lines) when the operator is given enough machines to keep him fully occupied. The effective relationship lies somewhat below the upper curve, but it should be borne in mind that these curves must be arbitrary to some extent, however small, since the assessment of psychological and physiological effort is partly subjective. Moll and Ulbricht arrived at their figures by assessing mental and physiological load factors for the fundamental operations which the operator has to perform.

Another desired effect of automatic operation is a reduction in the average time required to produce each component, i.e., the time obtained by dividing the sum of the set-up and machining times by the number of components produced. Owing to the increase in set-up time which frequently accompanies an increase in automatic operation, a reduction in average production time per component is only obtained if the size of batch being produced exceeds a certain value. This is shown clearly

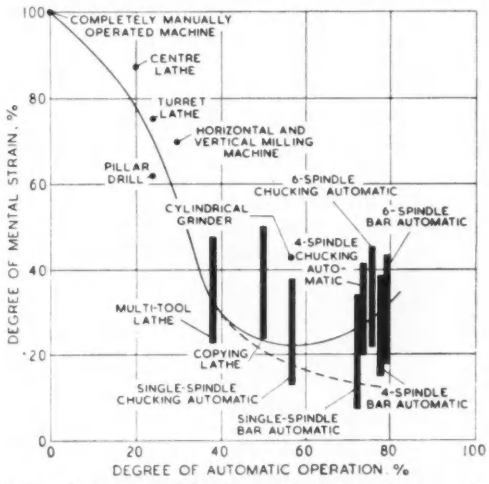

Fig. 2. Relationship between mental strain and degree of automatic operation.

in Fig. 3, in which average production-time curves are drawn for centre and turret lathes and for single- and six-spindle automatics, the component in each case being the same. The fact that the automatics yield the best production times for such small batches is because the component was rather large in this particular instance.

It is evident, from the previous paragraph, that the extent to which the production rate of a centre lathe may be improved by replacing it by a turret lathe or some kind

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† H. MOLL and W. ULBRICHT: "Heutiger technischer Stand und Entwicklungstendenzen in der Automatisierung der Fertigung, am Beispiel einer Automobilfabrik"; *Werkstattstechnik und Maschinenbau*, Vol. 47, p. 117.

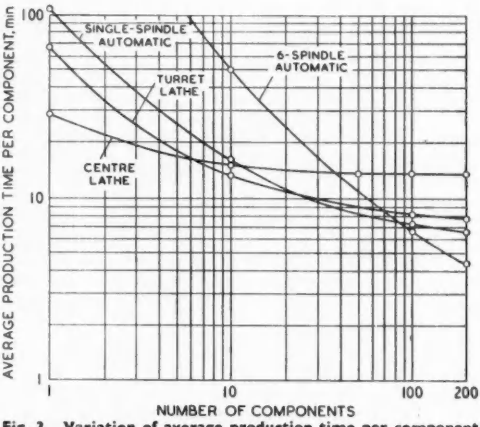


Fig. 3. Variation of average production time per component with number of components, for various types of lathe, in the case of fairly large components.

of automatic can only be discussed in terms of a specific component. However, a comparison can be effected by using average figures for the production rates of the various types of lathe. If, for each type, the production rate is expressed as a ratio of the capital cost of the machine, a curve such as that shown in Fig. 4 is obtained. It would appear from this curve that there may be an optimum ratio of production rate to capital cost which occurs with a degree of automatic operation lying between the turret lathe and the single-spindle automatic. This suggests a machine with almost the degree of automatic operation of the automatic and at a capital cost little greater than that of a turret lathe.

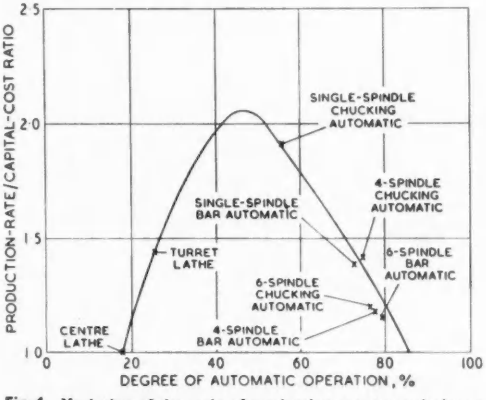


Fig. 4. Variation of the ratio of production rate to capital cost with degree of automatic operation.

It is the object of this survey to assess the feasibility of such a type of machine and to discuss its advantages and limitations. Although the argument so far has centred on the lathe, it is equally applicable to other kinds of machine tool, but it should be stressed that the discussion is concerned with general-purpose machines, the object being to increase their degree of automatic operation without sacrificing any of their versatility. For this purpose, it is considered desirable to summarize the basic requirements for the automatic production of components by means of machine tools, and to compare relatively inexpensive systems with numerically controlled machine tools, which have already formed the subject of a previous survey*.

Basic Requirements for Automatic Production

The automatic production of any component with machine tools can be divided into two fundamental stages, i.e., (1) setting up the machine, and (2) the actual machining and those functions connected with it which are a necessary technical part of producing the component. Loading and transferring between operations, where necessary, are theoretically inessential, but can rarely be eliminated, though they can be rendered more automatic. Except in such cases as transfer lines, these functions take place before and after the machining stage and neither affect the problem of control nor are affected by it, whereas setting-up time is affected.

Setting up the Machine

Setting up the machine is to some extent necessary, irrespective of how the machine may be controlled, but, until the advent of numerical control, a greater degree of automatic operation was always associated with increased setting-up time. Numerical control first brought automatic operation into the field of small-number production but, for many components, the cost of numerical control is too high. The economic problems of numerical control have been discussed in more detail by Millyard and Brewer†, and it is clear that, for many applications, automatic operation is often required for batch production. Numerical control is, however, inherently expensive and its cost cannot be reduced indefinitely, so that some alternative form of automatic or partly automatic control is evidently needed in the field of small-number production. It must nevertheless be accepted, *ab initio*, that such a form of control will undoubtedly demand a longer setting-up time.

Machining and other Essential Functions

The actual machining stage is where the real effect of automatic control is felt in small-number production and covers both machining itself and functional commands, such as the control of machine motions (speed and feed selection, turret indexing, etc.), and the supply of cutting fluid. Automatic machining involves the following steps:—

(1) *Processing of Numerical Information from the Drawing:*—

The information contained in an engineering drawing is rarely in a form which is directly useful for automatic production. For example, if a stepped shaft is to be turned, the drawing carries numerical information concerning the diameters of the steps, whereas, from the point of view of controlling the lathe, the displacements of the cross-slide are more important.

The amount of calculation needed to obtain the numerical information for controlling a machine tool may be simple and easily entrusted to the operator

* *Engineers' Digest Survey No. 5:* "The Numerical Control of Machine Tools", by R. C. Brewer. 2nd edition, revised and enlarged; September 1959.

† P. W. Millyard and R. C. Brewer: "Some Economic Aspects of Numerical-Controlled Machine Tools"; *The Production Engineer*, March, 1960, p. 141.

(though always with the risk of a miscalculation) or it may be so complex, as in the case of a three-dimensional surface, that only a digital computer can effectively perform processing of the data. Here, then, is the first requirement for a cheaper alternative form of control for batch production, i.e., that processing of the numerical information contained in the drawing must be done without the need for complex equipment. At the same time, of course, this imposes a limitation on the scope of the system, since any profiles which are more complicated than a straight line must, if accommodated at all, be handled by copying methods or form tools.

(2) *Storage of Control Information:—*

The information obtained from the drawing, when converted to a form suitable for automatic control, must be stored for a certain amount of time. For a single component or a small batch being produced under human control, the information for a specific operation is normally retained only during this operation. The use of decade switches and telephone dials in numerical control is an instance of this very limited retention of information in the field of automatic control, and might be called "short-time storage". For many forms of automatic control, the information is often stored only while the batch is being produced; this may be referred to as temporary storage, since the processing must be done again when the next batch is produced, one example being the setting of trips or dogs in capstan and turret lathes.

There is sometimes an advantage in being able to store this information permanently, e.g., by the punched cards or tape used in many numerical control systems. However, these conventional forms of permanent storage require quite costly readers and, at their present price level, cannot be considered for any inexpensive system of automatic control.

(3) *Numerical and Functional Commands:—*

The numerical information, calculated from the engineering drawing, must be used to control the machine tool and defines the required geometrical movements and velocities of the machine elements or, to use automatic control terminology, it is the *command information*. This information may be supplied to the machine by human agency (e.g., the lathe operator who has calculated that the cross-slide must move in by x inches) or automatically (by means of cams, tape or card readers, etc.) It is one of the chief disadvantages of many modern semi-automatic machine tools that this stage still requires a human operator.

The chief functional commands, in the case of a turret lathe, are as follows:—

(a) Selection of speed and feed in magnitude and direction.
(b) Indexing movements of the turret.
(c) Stopping and starting spindle rotation.
(d) Initiation of the various stages at the correct time and in the correct order for producing a component.

Again, these commands may be issued by human or automatic means.

(4) *Position Indication and Comparison with the Command Information:—*

Some means must be available for determining the actual position of each moving element and comparing it with the required position (command information), and this can be effected in one of three ways, i.e., continuously, step-wise, and discontinously.

With the continuous method, a constant check is made on the position of each moving element, and the motion is maintained all the time there is a difference between the desired and actual positions. To be strictly continuous, the check must be made automatically, hydraulic or electrical means usually being employed, though a form of continuous control is exerted by a craftsman watching the micrometer drum on his hand-wheel spindle.

With the step-wise method, the check is made at several discrete intervals and may consist of measuring the position of the moving element or checking the dimension itself with a gauge.

With the discontinuous method, the comparison is made only at the end of a motion. It is now impossible to exert continuous control, and the motion in question must be a simple basic movement of a slide, table, or tool-head along its ways (or two basic movements performed simultaneously under synchronized conditions). In this case, position indication and comparison can be effected in one unit by employing a device such as a limit switch, proximity switch, or light beam and photo-cell.

Tentative Specification for a Programme-Controlled Machine Tool

At this stage, it is possible to formulate a tentative specification for an inexpensive method of automatic operation, particularly suitable for small-number production. In this connection, it should be mentioned that there is a certain difficulty in terminology, inasmuch as the type of control to be discussed has various designations, such as automatic sequence control, automatic cycle control, and low-cost automation. It is, however, probably best known as programme control and, although some objection could justifiably be raised to this designation, it is commonly accepted and, for this reason, is used throughout this survey.

This tentative specification for programme control is based on the following stipulations:—

(a) Setting-up time may be appreciable.
(b) Loading and unloading may or may not be automatic.
(c) As the use of such items as cams is not envisaged, lead time will be relatively small for the degree of automatic operation considered.
(d) Calculation of command information from the engineering drawing will be carried out by human means.
(e) Storage of command information may be temporary or permanent, according to the application considered.
(f) Numerical and functional commands will be given to the machine automatically.
(g) Position indication and comparison will be effected not only automatically, but discontinuously, since this affords the opportunity of considerably reducing the cost, as compared with numerical control.
(h) There will be some method of ensuring that the various stages are performed at the correct times and in the correct sequence.

It will be appreciated from this specification that such a form of control will have limitations, mainly governed by the fact that only basic machine movements may be

used; for example, a milling machine will only produce plane surfaces and a lathe will only perform sliding and surfacing operations, unless some simple form of copying can be included in the control system.

Furthermore, for each operation, the moving element has only to be set in motion at the correct velocity and allowed to proceed at this velocity until it reaches its final position; thus, setting up the programme is largely a matter of specifying the functional commands. As with numerical control, it is easier to do this electrically (or electronically), although there is no inherent reason why it should not be done mechanically, hydraulically, or pneumatically.

Normally, some upper limit is placed on the number of stages in the programme (i.e., the number of steps in producing the component) and since, for each of these stages, any of the functions may be required, a rectangular array of controls, in columns and rows, suggests itself. The control may be two-way switches, push-buttons, or any other device which will make or break an electrical circuit. One very popular device is the plug-board with holes arranged in a series of vertical columns, the insertion of a plug in one of these holes making an electrical connection between two bus-bars or blocks located behind the board and, in this way, initiating the requisite operation.

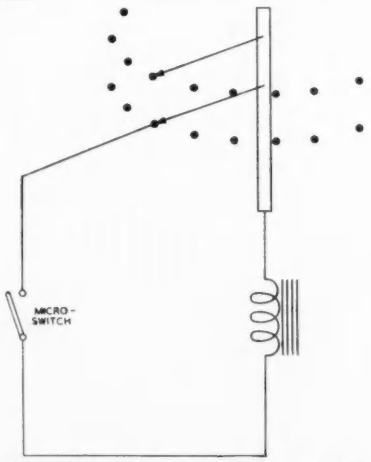


Fig. 5. The principle of the uniselector or stepping switch.

This initiation must occur at a definite instant of time, i.e., when the previous operation has been completed. A convenient way of accommodating the time element is to employ a stepping-switch or uniselector, which is a multi-way switch moving from one position to the next when a solenoid (contained in the switch) is energized, as shown diagrammatically in Fig. 5. Each contact of the lowest deck of the switch is connected to a micro-switch whose contacts make at the conclusion of the relevant operation and which is usually the means by which accurate positioning is achieved as well. Closure of the micro-switch contacts completes the circuit through the solenoid, causing the arms of the switch to move forward to the next position. This movement breaks the solenoid circuit, and it remains broken until the next operation is complete.

Many of the functions commanded, such as feed selection, cross-slide movement, turret indexing, etc., require power at some level, and this may be provided electrically, hydraulically, or pneumatically, as will be seen later. Of the different ways in which the subject might have been treated, the author has chosen to consider separately each type of machine tool to which this type of control can be applied, i.e., lathes, milling machines, boring machines, and gear-hobbing and gear-grinding machines.

PROGRAMME-CONTROLLED LATHES

Because of its lack of provision for multi-tooling, the centre lathe has been comparatively neglected in applying programme control, by far the greatest number of applications having been to some variation of the turret or capstan lathe. One of the few exceptions is the copying lathe but, in most cases, the control has been limited to

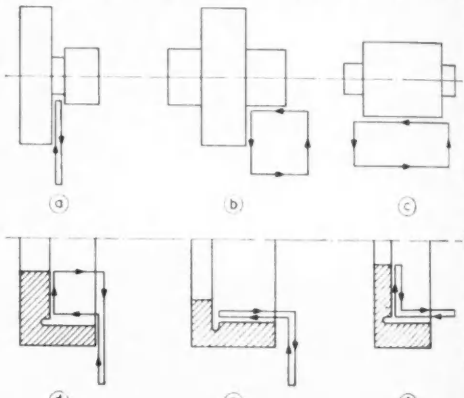


Fig. 6. The six standard programmes of the Heyligenstaedt "Heycomat" copying lathe.

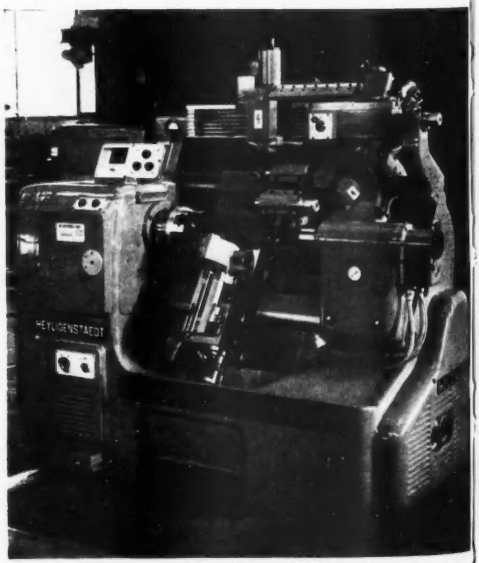


Fig. 7. The programme-controlled "Heycomat" copying lathe.
(Courtesy of Heyligenstaedt und Comp. Werkzeugmaschinenfabrik G.m.b.H.)

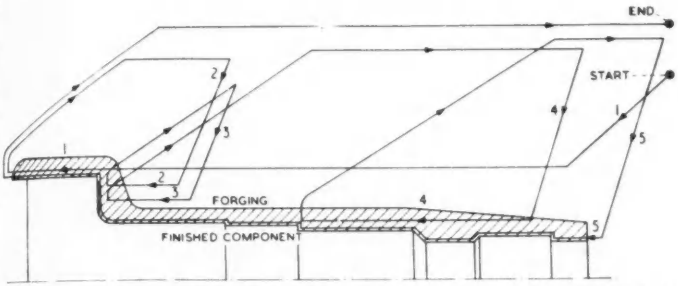


Fig. 8. Diagrammatic representation of a programme for rough- and copy-machining a forging.

the selection of longitudinal feeds and possibly to the programming of the cuts for a multi-cut lathe. The new Heyligenstaedt "Heycomat" copying lathe, however, offers the possibility of reducing copying time by the addition of an automatically programmed auxiliary carriage, which has the six programmes shown schematically in Fig. 6. Where kinematically possible, operations from this auxiliary carriage can proceed simultaneously with normal copying operations. A view of the programme-controlled "Heycomat" copying lathe is shown in Fig. 7.

Similarly, a number of copying machines made in Czechoslovakia have been equipped with programme control, these varying from quite simple to fairly complex systems capable of programming a series of roughing cuts before the finishing cut, which is made under template control, as shown in Fig. 8, which is a diagrammatic representation of a programme for rough- and copy-machining a forging.

The "S Pilote" copying lathes of the French company, H. Ernault-Batignolles, have a rather unusual system of permanent storage, i.e., two separate punched cards.

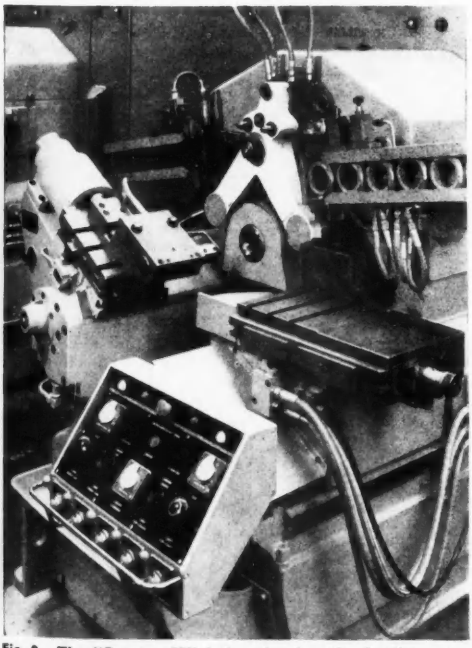


Fig. 9. The "Frontor 35" lathe, showing the loading arm. *(Courtesy of J. G. Weisser Söhne)*

One card, which is quite short and is wrapped round a small-diameter drum, has five channels and prepares the machine for a specific mode of operation; for example, along the card there are four positions (for each channel) which may be punched with a rectangular hole and, in the channel marked "cycle restarts", the punching of one or more holes indicates how many cuts will be taken (up to a maximum of four). The other four channels are for feed reduction, rapid traverse, reverse feed, and cross-feed slide.

It should be noted that the shorter card only *prepares* the machine and, unless the longer card, which is wound round a larger-diameter drum, is also punched in a corresponding manner, the operation will not take place. The longer card, however, has another function, i.e., that of controlling the travel of the tool, which is effected through the length of a rectangular hole punched in it. The time taken to prepare these cards is less than that required for setting the dogs on a conventional machine, so that, if the accuracy obtained is comparable, the Ernault-Batignolles system represents an appreciable step towards the reduction of lead and set-up times.

The "Synchromat" lathe manufactured by Salomé Frères is a special type of centre lathe with two hydraulically operated carriages, but these carriages are mounted one above the other on four slides lying in a vertical plane, so that the radial movement of their cross-slides is vertical and not horizontal. The movements of the carriages and cross-slides can be programmed to follow a chosen cycle of operations and, for each operation, the spindle speed may be preselected by means of a plug-board mounted on the headstock. Apart from conventional stepped turning, double- and multi-cut copying operations can be programmed.

The new "Frontor 35" semi-automatic lathe, manufactured in Germany by Weisser, is intended for short workpieces and is operated from what would normally be called the tailstock end of the machine, but which now becomes the front of the machine, considerably reducing walking time when several machines are handled by one operator. A view of one of these machines is shown in Fig. 9, in which the loading arm can be seen above the chuck. On completion of the last slide motion, the loading arm swivels, so that the blank-holder takes a new blank from the feeding attachment while the finished-product arm takes the workpiece from the chuck. The loading arm then rotates through an angle of 80 deg., and the new blank is placed in the chuck while the finished workpiece is placed in the ejector slide, the time for loading and unloading being 8 sec. The feeding and ejector slides are made adjustable, so that work of different sizes can be accommodated.

The control unit of the Weisser "Frontor 35" lathe has six definite turning programmes, which are illustrated

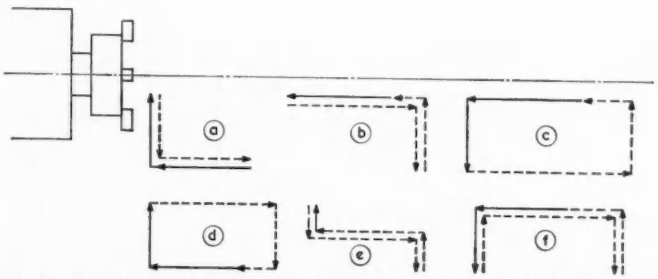


Fig. 10. The six programmes of the control system for the "Frontor 35" lathe.

schematically in Fig. 10, the dotted lines indicating rapid feed. (Dotted lines are used to indicate rapid feed in all subsequent illustrations.) If the machine is hydraulically controlled, programmes (e) and (f) are not available. In all cases where there is a change-over from rapid traverse to normal feed (indicated by solid lines) during one straight-line motion, the change-over point can be anywhere along the line. If the machine is not equipped with a loading arm, the work spindle is automatically braked on completion of the work cycle, and the chuck is opened by operating a foot-switch. Definite spindle speeds from 95 to 1500 rpm are obtained by means of pick-off gears. Feeds, hydraulically powered, are infinitely variable from 0·002 to 0·028 in./rev. The method of selecting the spindle speed is perhaps not as satisfactory as it might be, even though the manufacturers claim that the pick-off gears "are arranged on a multiple-spline shaft and can easily be removed by means of a special key"; on the other hand, for the simple turning programmes envisaged on this type of lathe, any provision for automatic speed selection would be of help only in setting up the machine, since there are no speed changes within the programme. A number of auxiliary attachments, such as copying units, hydraulically actuated toolposts, etc. are available, if required.

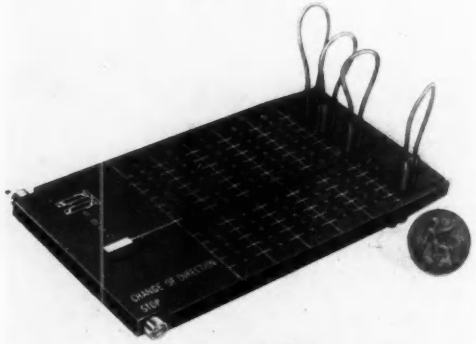


Fig. 11. The plug-board of the Herbert programme-control system.
(Courtesy of Alfred Herbert Ltd.)

Applications to turret lathes have varied quite considerably in complexity. A comparatively simple system is that used by Alfred Herbert Ltd. for their own No. 2D capstan lathe, the only functional command being control of spindle speed. The essential parts of the system are a plug-board and limit-switches. The plug-board has twelve vertical columns of holes, arranged in six pairs and numbered from one to six, corresponding to the turret stations, and any desired function is brought into operation by short-circuiting the relevant pair of holes with a short plug lead, as shown in Fig. 11. There are thirteen rows of holes corresponding to the various functions to be controlled, as follows:—

Rows 1 and 2 are for the selection of the direction of spindle rotation; for each turret face a plug must be inserted in one of these two rows. Rows 3 to 6 determine the speeds at which the motor runs, and one of these rows must be selected according to the desired speed. Continuing the usual practice of the company, a four-speed pole-changing motor is employed as the basic source of speed change. Rows 3 to 6 are coded *A*, *B*, *C*, and *D* on the plug-board.

Rows 7 and 8 are colour-coded yellow and blue on the plug-board and make it possible to provide eight speeds for any given programme. Actually, however, the machine has sixteen speeds, since there is a pair of pick-off gears which can provide either a normal speed range of 160 to 2550 rpm or a low speed range of 50 to 810 rpm, though one or the other speed range must naturally be selected for a given programme.

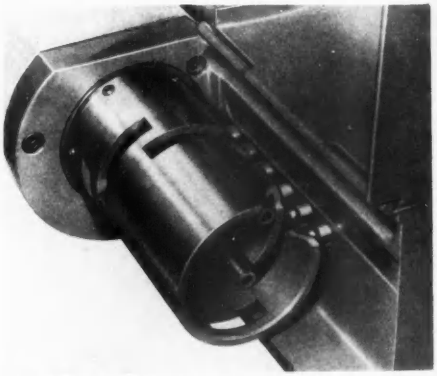


Fig. 12. The stop-barrel and pegs for operating the limit-switches in the Herbert programme-control system.
(Courtesy of Alfred Herbert Ltd.)

Rows 9 to 11 are spare rows on the present system, while row 12 is provided for changing the direction of spindle rotation and is used for such operations as tap withdrawal. Row 13 provides the function of stopping the spindle.

In operation, the appropriate column of holes is selected by limit-switches which are operated by pegs on a stop barrel (Fig. 12); thus, since the programme consists solely of varying the cutting speed at times when the turret is indexed, the turret itself can be used instead of a stepping switch. The machine is equipped with the standard Herbert automatic weight-operated bar-feed unit and air-operated chuck, enabling the bar to be fed forward by a preset amount, and the system is so arranged that the chuck will remain open unless the bar is fed forward by the correct amount.

Programme control for spindle-speed selection and direction of rotation is also fitted, for example, to

French-made Saviem lathes and to the British-made "Accuratool" lathe distributed by Dowding & Doll Ltd.

In Italy, Minganti have extended control of functional commands to feed, as well as speed, and the actual physical process of setting up the programme is somewhat easier. Instead of a plug-board, use is made of a panel, mounted on the front of the headstock, with ten rows of horizontal slots in which push-button knobs slide. Thus, each horizontal row is, in effect, the deck of a multi-way switch straightened out, the movement of the knob corresponding to the motion of the contact arm. From Fig. 13, it will be seen that there are two push-button

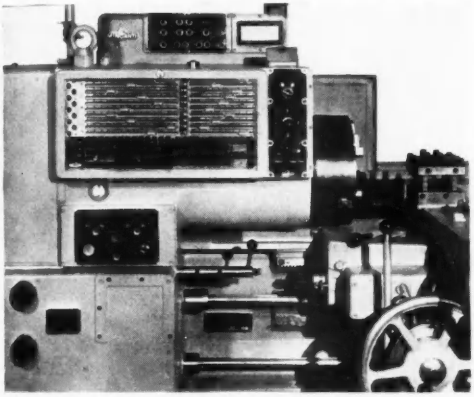


Fig. 13. The control panel of the programme-control system for Minganti lathes.
(Courtesy of Giuseppe Minganti & C., s.p.a.)

knobs for each row; for a given row, the left-hand knob can be set in any one of twelve positions corresponding to 12 spindle speeds, and the right-hand knob in any one of eight positions corresponding to 8 basic feeds, though there are, in fact, gears similar to pick-off gears which may be used to increase the number of actual feeds by simple multiplying, giving 16 longitudinal feeds for the hexagon turret and 48 longitudinal and 48 cross feeds for the square toolpost. The upper six rows of slots on the control panel correspond to the stations of the hexagon turret, while the lower four refer to the positions of the square toolpost. Pilot lamps illuminate to show which turret or toolpost is working at that instant. All gears run in constant mesh and speed changing is effected in the following manner:—

Driven gears are mounted on, or are integral with, sleeves which rotate freely on the driven shaft. Each sleeve is connected to one set of friction discs of an electromagnetic clutch, and the other set of discs to the driven shaft, so that, as soon as a given clutch is excited, the gear on the corresponding sleeve is coupled to the driven shaft. These clutches are actuated by electrical circuits set by the push-buttons on the control panel and closed through contacts corresponding to the faces of the hexagon turret. Indexing of the square toolpost is not automatic and, on rotating from one position to another, the four-way switch at the right-hand side of the control panel must be reset to its new position. The automatic operation of the hexagon turret can be dispensed with by setting the "schedule cycle switch" to the "OFF" position; in this case, speeds and feeds may be commanded at the time required by moving the push-botton knobs to a new position. The general kinematic scheme of the Minganti system is shown in Fig. 14.

The versatility of the machine may be further increased by optional auxiliary attachments, such as taper-turning and hydraulic copying mechanisms. The Minganti 50 E automatic is equipped with a similar system of control but, for these machines, the cross-slides derive their feed motion from that of the hexagon turret and not independently, as is the case with the square toolpost of the turret lathes. For this reason, the control panel has only seven rows of slots, six for the stations of the hexagon turret and the seventh for semi-automatic operation, i.e., for using the machine as a turret lathe, rather than as an automatic lathe. For this semi-

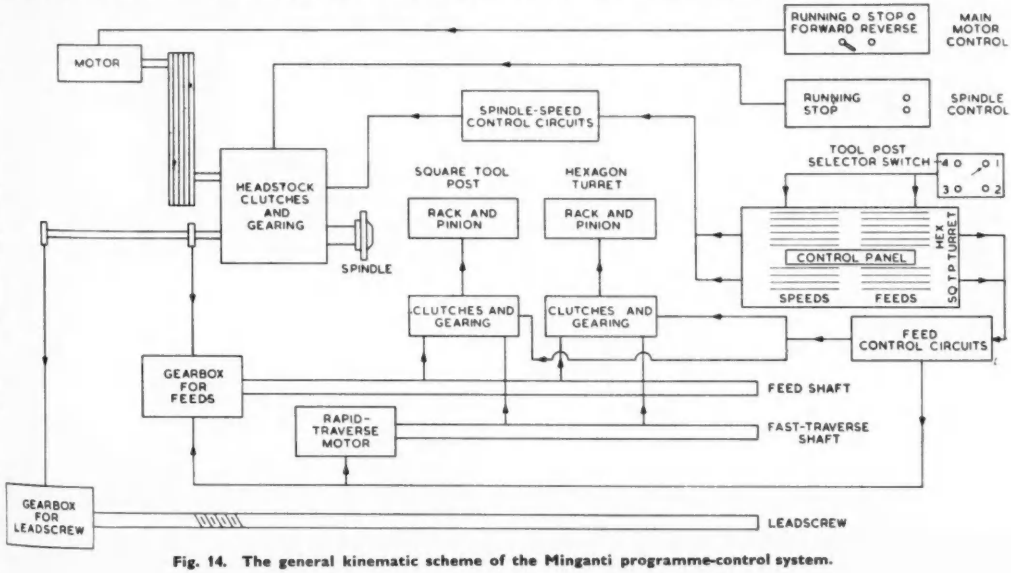


Fig. 14. The general kinematic scheme of the Minganti programme-control system.

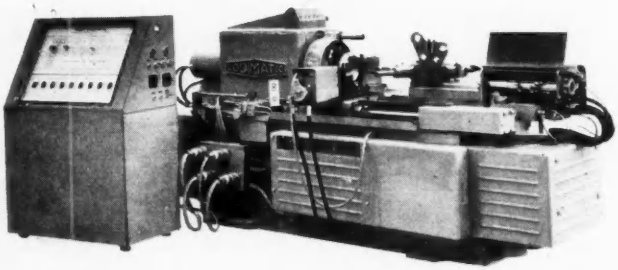


Fig. 15. The "Codimatic" programme-controlled turret lathe.
(Courtesy of E.U.S.D.)

automatic operation, a square toolpost is available with seven working feeds to either of two ranges of feed. The machine can be equipped to work as either a chucking or bar automatic.

In Hungary, the model RT8OP turret lathe, marketed by Technoimpex, and the "Codimatic" turret lathe, manufactured in France by E.U.S.D., are also equipped with programme control for spindle-speed and feed selection, but are set up by means of a conventional plug-board. A general view of the programme-controlled "Codimatic" turret lathe is shown in Fig. 15, and a close-up of its plug-board in Fig. 16.

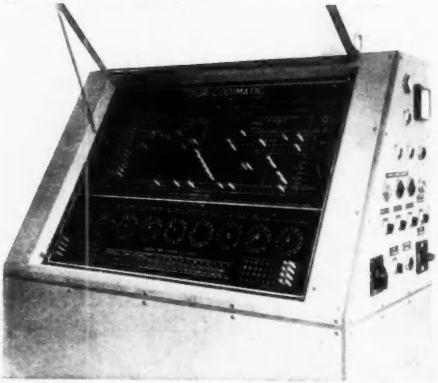


Fig. 16. Close-up of the plug-board used in the "Codimatic" programme-controlled turret lathe.
(Courtesy of E.U.S.D.)

One interesting variation on the plug-board/push-button theme is that used by Liechti in Switzerland, in conjunction with their DR 650 chucking automatic, which is intended principally for workpieces of high diameter/length ratio. The most characteristic feature of the machine itself is that it has two completely independent turret slides, each with four indexing stations and its own built-in copying unit. The most interesting feature of the control system, however, is the use of two punched steel bands as the means of programming the machine; thus, the system provides a permanent means of storing the numerical information, whereas the previous systems merely offer temporary storage.

In this Liechti system, small rivets are inserted into holes in the steel bands to give the required programme (Fig. 17), and the purely mechanical system of control is initiated by compressed air, so that the system has, in effect, a "pneumatic reader". A small rotary piston compressor supplies compressed air for the machine, an air reservoir ensuring a constant supply pressure. The turret slides can be moved at any one of twelve standard feeds longitudinally and/or transversely. Selection of feeds and spindle speeds, together with operation of the clutches for reversal of direction and changing from fast to normal feed rate, is automatically controlled by the steel bands. Facilities are also provided for copying operations.

One British system which carries the degree of mechanization virtually to that of a single-spindle automatic is that produced by Nickols Automatics Ltd. So far, the system has only been applied to the most popular sizes of Ward and Herbert capstan lathes, but the company is preparing equipment for larger capstan and turret lathes and these will be available in due course. A great advantage of the system is the ease with which conversion can be made, and, indeed, reconversion of the machine to its original form, if necessary. A general view of a Ward capstan lathe, converted for automatic operation with the Nickols system of control, is shown in Fig. 18, from which it will be seen that several standard items of equipment have been removed, while other

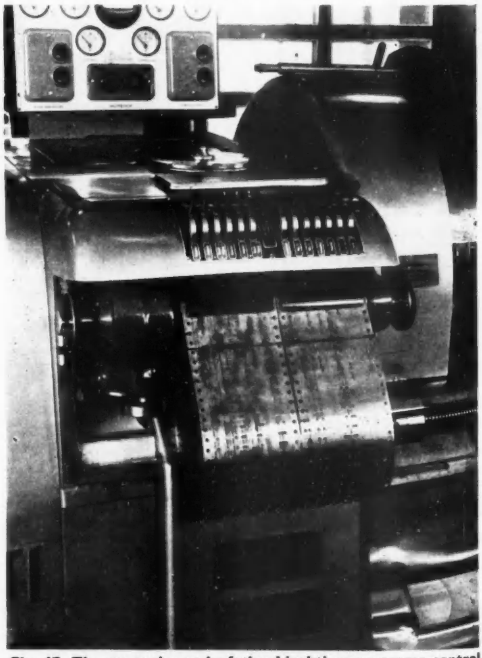


Fig. 17. The control panel of the Liechti programme-control system, showing the punched steel band and rivets.
(Courtesy of Liechti & Co. Ltd.)

Fig. 18. A Ward capstan lathe fitted with the Nickols programme-control system.
(Courtesy of Nickols Automatics Ltd.)

auxiliary items (mainly pneumatic) have been added to the machine. There is, of course, no reason why a capstan lathe should not be designed to incorporate these items as an integral part of the machine tool and, as the concept of programme control gains favour, there will undoubtedly be lathes specially built for this form of automatic control.

The principal additions and alterations are as follows:—

(a) To control the movement of the cross-slide, one air-operated cylinder is bolted to the rear vertical face of the cross-slide, and a second to the rear vertical face of the saddle. The piston rods of these cylinders are connected at their free ends by a vertical coupling-plate, so that, if air is admitted to the right of the piston in the lower cylinder, the piston will be driven to the left-hand end of the cylinder, and the coupling-plate becomes effectively fixed, as shown in Fig. 19. If air is now

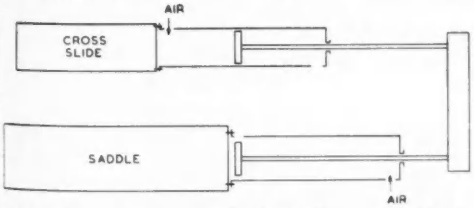


Fig. 19. The pneumatic system for driving the cross-slide in the Nickols programme-control system.

admitted to the left of the upper piston, the cross-slide will be driven to the left, movement of the cross-slide in the opposite direction being achieved by admitting air to the right of the upper piston and to the left of the lower

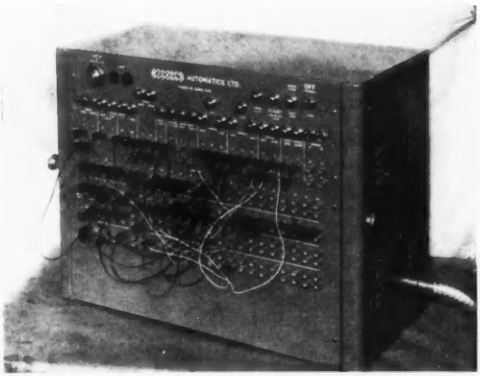


Fig. 20. The control cabinet of the Nickols programme-control system.
(Courtesy of Nickols Automatics Ltd.)

piston. The air pressure employed is 80 to 100 psi and provides sufficient force for a high rate of traverse; hydraulic check cylinders are used to obtain the final slow-down automatically, these cylinders being actuated by the coupling-plate coming into contact with an adjustable nut on the piston rod of the check cylinder.

(b) The turret locking handle has been removed and replaced by an air cylinder and piston. Indexing by the normal mechanism can proceed if there is no air pressure on top of the piston.

(c) The normal disc at the rear end of the turret slide has been removed and replaced by one of larger diameter. The normal turret stops are screwed into this disc but, in addition, six long screwed rods are carried by the disc near its periphery, these rods being steadied at their free ends by an annular member. Each rod carries a stop collar which can be positioned by two lock-nuts. As the turret slide moves forward, a point is reached at which the relevant stop collar contacts a pivoted roller, operating a limit-switch which energizes the circuit for the slow feed rate.

(d) The handwheel for moving the capstan slide has been replaced by a pinion which meshes with a hydraulically driven rack. The pinion, rack, and hydraulic circuitry are contained in the cast cover, which can be seen in the left foreground in Fig. 18. The limits of movement are controlled by micro-switches, and hydraulic check cylinders are again used to actuate a final slow-down.

(e) A pinion is mounted on the feed-shaft (instead of the usual change lever) and this meshes with a gearwheel whose position is changed by a lever mechanism operated by two small air cylinders. In this way, mechanization of feed selection is achieved very easily.

(f) Selection of spindle speed depends on how these speeds are derived. In the case of the Herbert No. 2D capstan, the four basic speeds are obtained by pole-changing, so that standard electrical circuitry can be used. Each of the four basic speeds provides two speeds through standard gearing, the speed required being obtained by setting a clutch to select either the high or low speed. In applying the Nickols system to Herbert lathes, a solenoid valve has been used to obtain the correct clutch setting.

The control cabinet is shown in Fig. 20, and its actual size may be judged by comparison with the lathe itself in Fig. 18. The front panel of the cabinet consists of

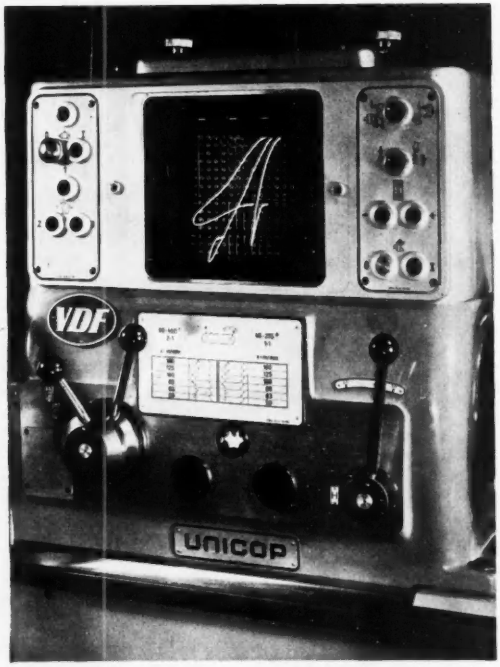


Fig. 21. The plug-board on the "Unicop" copying lathe. (*Courtesy of Heidenreich & Harbeck*)

two half-panels, the upper of which is a standard unit. The lower half-panel may be varied to suit the particular machine to which the system is applied, but it will normally carry four horizontal rows of single-pin sockets (24 in each row in the panel shown in Fig. 20). In the lower half of the cabinet, the only component is a multi-way stepping switch. The sockets on the front of the lower half-panel are connected in quadruplets to the four banks of contacts of the stepping switch, which thus serves as a distributor, since each column of four sockets on the front of the panel is energized successively as the wiper-arm of the switch moves around the contacts.

With regard to the upper half-panel, it will be seen from Fig. 20 that there are two horizontal rows of sockets which are labelled to indicate their functions. The sockets in the upper row, collectively termed *Motions*, are concerned with spindle speeds, feeds, and the motions of the cross-slide, turret, etc. The sockets are permanently connected to the solenoids of the air-cylinder control valves. The sockets in the lower row are connected to the various micro-switches on the machine and are collectively called *Signals*, because they provide the signals that certain operations have been completed and that the stepping-switch wiper-arm should move to the next contact.

In addition to the setting time for the capstan itself, there is an additional time, of the order of 10 to 20 minutes, for setting up the automatic controls. As already mentioned, the upper half-panel of the control cabinet carries two rows of sockets, one for motions and the other for signals. For each operation, one or more of the relevant four sockets on the lower half-panel are connected by plug leads to the requisite *Motions* and *Signals* sockets. Thus, to summarize, the sockets in the upper half-panel are concerned with the functions which have to be performed and with the information that they have been completed, while the sockets in the lower half-panel provide a convenient method of grouping functions for the various operations to be performed, and the stepping switch ensures that the operations are performed in the correct order and, in conjunction with the micro-switches on the machine, at the right time.

All new turret lathes manufactured by the Vereinigte Drehbank Fabriken (VDF) group of German companies incorporate programme control for spindle-speed and feed selection, the sequence of speeds and feeds being permanently stored on a punched card prepared in the planning department. The operator has merely to insert plugs in a plug-board according to the pattern of holes on the punched card, but indexing of the turret must still be performed manually.

The VDF "Unicop" copying lathe, manufactured by Heidenreich & Harbeck, is also equipped with a form of programme control for normal and rapid feeds and spindle speeds, the limits of movement being governed by micro-switches actuated by trip-dogs. There are eight slots in which these trip-dogs can be set and, since these slots are scanned in succession, eight different patterns of motion along each axis can be set up and interpreted unequivocally by the control system. Setting the sequence of operations is effected by joining pairs of sockets, one in an upper panel and the other in a lower panel, as shown in Fig. 21, in a manner similar to that described in connection with the Nickols system.

A machine of comparable versatility is the AB-80 lathe made in Czechoslovakia by MAS and marketed by Strojexport. As will be seen from Fig. 22, this has a substantial turret drum which indexes about a horizontal axis parallel to the spindle axis. Movement of all three cross-slides, bar feeding and clamping, and indexing and fixing of the turret drum are carried out hydraulically and may be automatic if the programming system is used.

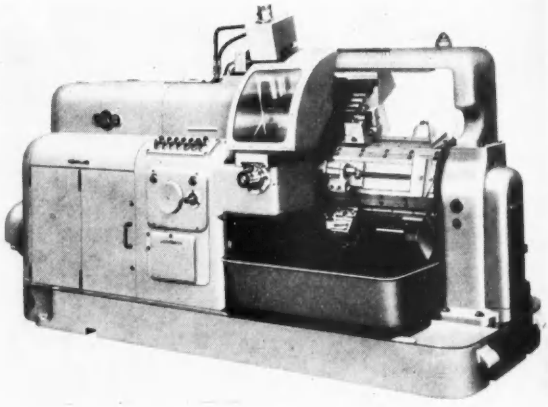


Fig. 22. The MAS AB-80 lathe, specially designed and built for programme control. (*Courtesy of Strojexport*)

Interest in vertical turret lathes has increased considerably in recent years, probably because of the more serious attention which has been given to the problems of batch production. Vertical turret lathes are very suitable for the application of programme control, the principal functions to be controlled being spindle speed; magnitude of feed, including rapid traverse; direction of feed; tracer operation, if incorporated; and selection of turret stations.

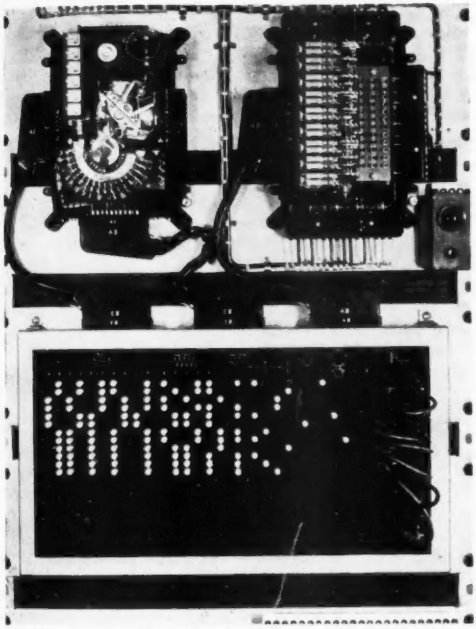


Fig. 23. The plug-board of the Dörries programme-control system.
(Courtesy of O. Dörries A.G.)

In the system employed by the German company, O. Dörries A.G., for their vertical turret lathes, the plug-board has twenty-seven columns (corresponding to the functions to be selected) and twenty rows (corresponding to the number of operations in the programme). In this plug-board, illustrated in Fig. 23, the first ten columns (from the left) are for selecting spindle speeds, and the next six columns are for selecting the magnitude of normal power feeds. The machine, however, has 24 spindle speeds and 16 feeds, so that it will be clear that the number of columns required has been considerably reduced by using what appears to be a coding system but which is, in fact, based on the combinations of clutches and gears to derive any desired speed or feed.

A further column is used for rapid traverse and four columns for selecting the eight directions of feed, these four columns referring to what might be arbitrarily called north, south, east, and west; the remaining four directions are at 45 deg. to the main directions and are obtained by inserting two plugs (instead of one), this having the effect of commanding two movements at right angles, so synchronized that the resultant direction of movement is at 45 deg. to either.

The next column is for tracer control, and the remaining five columns are for selecting the requisite turret station for a particular operation. The length of travel at each stage of the programme and the origination of the next stage are governed by contacts made by limit-switches and trip-dogs which are set according to the length of travel required. Unclamping and indexing of the turret are effected by an electric motor driving through an epicyclic gear train, thus providing a convenient method for the selection of any desired turret station.

The model KEA–100 vertical turret lathe, manufactured in Germany by Schiess, has also been provided with programme control. In this lathe (Fig. 24), the control system is electrical in nature and is housed in a separate cabinet, and programming is performed by inserting plugs in a plug-board. Programming involves the selection of spindle speed, feed, turret station, and direction of movement of the turret (up, down, left or right). The programme "memory" is divided into five preselection groups corresponding to the five turret positions, and these can be used in any desired sequence. Each group contains twelve stages, so that a total of sixty automatic control operations is available in any desired sequence. It is quite immaterial how the total number of stages is divided between the horizontal and vertical traverses.

The main gearbox provides sixteen speeds, and the selection of the desired speed is achieved by actuating relevant electromagnetic disc clutches. It is possible to change the speed automatically while the turret is being traversed horizontally, so that, by changing the speed in steps, facing work can be done with an approximately constant cutting speed. Feed selection is also achieved in a similar manner, four electromagnetic clutches being sufficient for the twelve feeds. Indexing of the turret is carried out electromechanically.

Another German company, Max Müller, manufacture their "Eltropilot" programme-control system mainly for use with their centre, facing, and turret lathes, but this system is in a fairly universal form and is thus

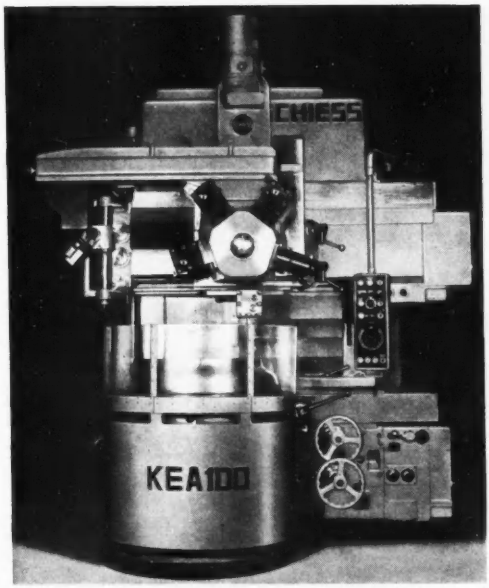


Fig. 24. The Schiess KEA-100 programme-controlled vertical turret lathe.
(Courtesy of Schiess A.G.)

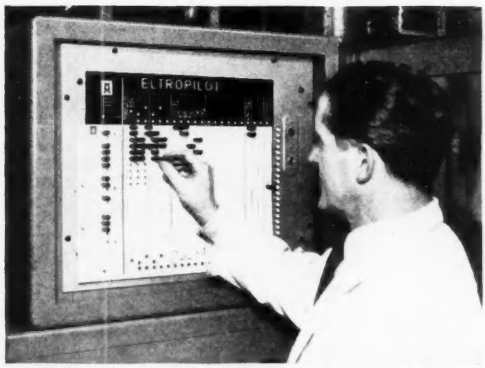


Fig. 25. Setting up the plug-board of the "Eltropilot" programme-control system with the aid of a punched card.
(Courtesy of Max Müller, Brinker Maschinenfabrik)

capable of wider application. Applied to a lathe, it will control movements of machine elements (saddle, cross-slide, drilling attachments, etc.) and operational conditions (spindle speed, direction and magnitude of feed, rapid traverse, etc.). With the object of improving machine-utilization time, attention has been given to the possibility of increasing the amount of setting-up work which can be carried out while the machine is working normally. One step in this direction, although not unique to this system, is the punching of a guide-card which the operator places over the plug-board when inserting the plugs; not only is it likely to be punched more quickly in the planning office, but this card obviously reduces the actual time of setting up the machine. Fig. 25 shows the plug-board being set up with the aid of the guide-card.

One concept which saves rather more time is a detachable dog-setting plate, which enables setting of the dogs to be effected away from the machine. When the machine is ready to begin a new batch of work, the dog-setting plate is located on the machine by means of dowels. Even with dowel location, however, it will be evident that dog-setting by remote control is not accurate enough for most purposes, and fine adjustment of the control positions is effected by moving the limit-switch slightly. Fig. 26 shows the dog-setting plate, with the dogs set according to the planning sheet.

A final saving in machine idle-time is effected by the use of tool-holder units which, like the dog-setting plate, can be set up in advance and can quickly be bolted onto the machine. This concept of tool-setting does not, of course, eliminate all machine idle-time due to tool-setting, and the proportion which it does eliminate is dependent on the component being made.

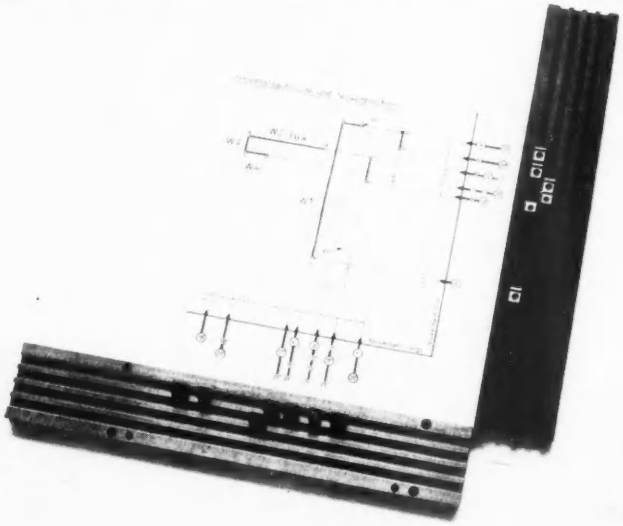


Fig. 26. The dog-setting plate of the "Eltropilot" programme-control system, set in accordance with the planning sheet.
(Courtesy of Max Müller, Brinker Maschinenfabrik)

The "Eltropilot" plug-board is divided into two sections. The right-hand section (to the right of the thick vertical line in Fig. 25) is similar to the conventional plug-board inasmuch as it controls, for the various stages in the programme, spindle speed, feed (sliding and surfacing) in both magnitude and direction, rapid traverse, copying, etc., and has 21 columns and 20 rows. Where a plug is inserted, an impulse is transmitted at the correct time to a relay which actuates the controlling circuit for that particular function. The command to terminate the motion of a machine element and to proceed to a new stage in the programme is given when a micro-switch is operated by one of the dogs. During the complete cycle, a dog may move over a given micro-switch several times and yet not be intended to actuate the micro-switch on each occasion. For this purpose, the left-hand section of the plug-board is normally provided with only three vertical rows. A plug is inserted into this section only when it is intended that the contact between dog and micro-switch should terminate a movement and initiate the next stage of the programme.

The Swiss Menziken vertical lathe is controlled by punched cards with regard to selection of spindle speed and feed and the sequence of operations. One of its most interesting features is a magnetically operated tailstock, which is adjustable for pressure and which is compensated for expansion of the workpiece.

PROGRAMME-CONTROLLED MILLING MACHINES

The milling machines to which programme control has been applied are necessarily those which are the most versatile, i.e., the vertical and plain horizontal machines, although one or two companies have applied this form of control to a universal machine, including programmed rotation of the indexing head.

A quite appreciable amount of milling operations can be covered by a fairly unpretentious control system, e.g. that applied to the milling machines manufactured in Germany by Union Werkzeugmaschinenfabrik M. Reuther K.G. For setting up the machine and for

machining small quantities, manual control can be effected by means of a pendant push-button panel, while for partially or completely automatic operation there is a basic work cycle on which about a dozen variations can be made merely by setting two six-way switches mounted on the side of the column.

The basic cycle of table movement comprises the cutting stroke, in which rapid advance is followed by movement at normal cutting feed rates, and the return stroke, which is a rapid traverse initiated by push-button control. The different programmes for these milling machines are shown schematically in Fig. 27, in which Fig. 27a shows a simple cutting stroke followed by a return stroke. The first variation on this basic cycle is that the rapid return stroke may be automatic (Fig. 27b). A second variation is that, during the cutting stroke, the machining part of the stroke is interrupted by a rapid traverse, trip-dogs and intermediate limit switches setting the points at which transition from the rapid-to-normal or normal-to-rapid condition takes place. This interrupted cycle may also be programmed for a manually initiated return stroke (Fig. 27c) or an automatic return stroke (Fig. 27d), and these four variations can be performed with the cutting stroke either from left to right or from right to left, giving eight variations in all. The three four-stroke cycles shown in Fig. 27e, f, and g add slightly more versatility to the machine and complete the store of programmed cycles.

A system which is very similar to the above is that used by Fritz Werner A.G. for their horizontal and vertical milling machines, but the Werner system can incorporate automatic indexing in any of the basic cycles, if required. Also, the Hungarian MU-320 universal milling machine, marketed by Technoimpex, can be equipped with a form of programme control which permits the selection of any of twenty standard cycles of table movement.

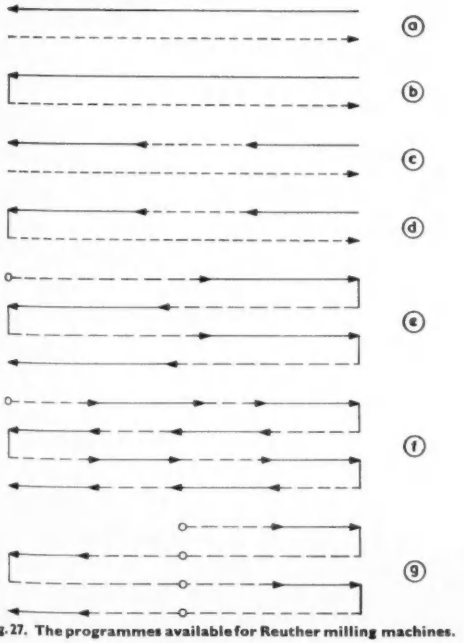


Fig. 27. The programmes available for Reuther milling machines.

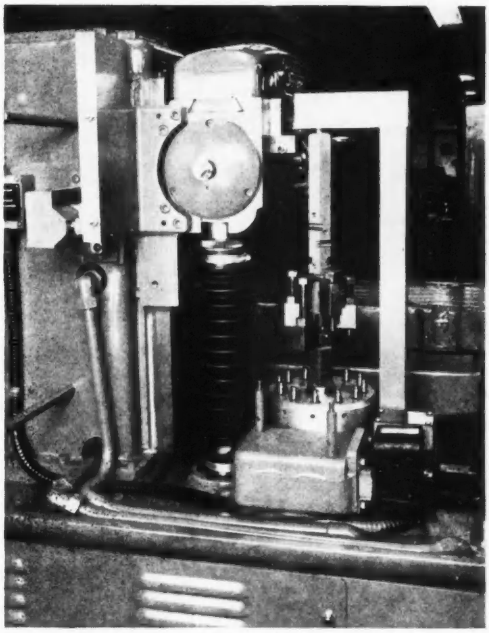


Fig. 28. The indexing turret for the head programme of the Centec programme-controlled milling machine.
(Courtesy of Centec Machine Tools Ltd.)

The "Rumag" programme-controlled milling machines manufactured in Germany by Roth und Müller have a very simple basic concept, i.e., that of table movement at rapid and normal feed rates alternately. As many trip-dogs as desired (or can be physically accommodated) can be set along the table and, when limit-switches are passed, the table motion changes in the sequence rapid-normal-rapid-normal, etc. This programme would place rather a severe limitation on the number of components which could be milled, if it were not for the fact that more than one motion is controlled; in the case of the horizontal machine, the longitudinal motion of the table and the vertical motion of the knee are controlled, while the vertical machine effects a three-dimensional control—the table longitudinally, the saddle transversely, and the spindle-quill vertically.

The different stages of the cycle are initiated by the limit-switches according to a programme set up on rotary switches on the control panel. The trip-dogs are carried in slots on a programme-plate fitted to the moving member, and these programme plates are easily detached and can be replaced by others when a new component is to be produced. At the end of a traverse, the trip-dog causes a brake to be applied to the spindle motor for one second and, on release of this brake, the return stroke is made at rapid traverse to either the original or to some new starting point. If desired, application of the brake can be delayed up to 10 seconds by switching in a time-relay. Two push-buttons marked "Halt" and "Start" can be used to interrupt and re-start the programme at any desired point, and a further button, marked "Motor Halt", switches off the motor independently of the table movement.

A British company, Centec Machine Tools Ltd., has recently introduced its Series-3 programme-controlled

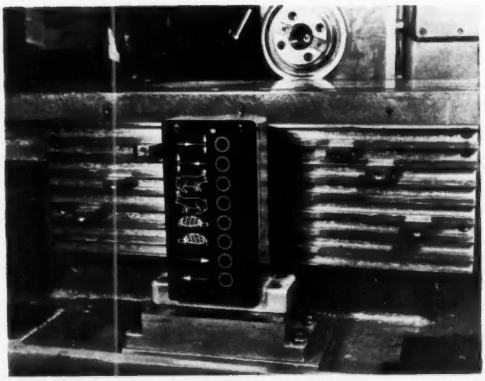


Fig. 29. The control slide for the table programme of the Centec programme-controlled milling machine.
(Courtesy of Centec Machine Tools Ltd.)

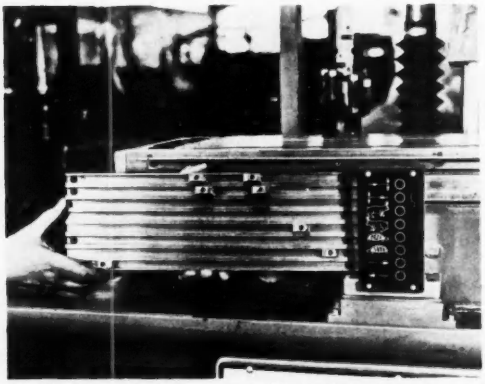


Fig. 30. Removal of the control slide for the table programme of the Centec programme-controlled milling machine.
(Courtesy of Centec Machine Tools Ltd.)

horizontal milling machines. Like the "Rumag" machines, these machines are also programmed for horizontal and vertical motions. Thus, in the head programme, the height of the cutter head above the table can be set to any one of six preselected values by means of the indexing turret shown in Fig. 28. The uppermost position of the head is, in effect, the datum and each time the head reaches this position the turret indexes to a new position, ready for the next down-stroke. When the head is fed down, it continues its motion until it is stopped mechanically by the relevant turret stop. The head motion has rapid approach movements, and change-over to normal feed rates is effected by trip-buttons positioned in slots on a control slide similar to the one illustrated for the table programme in Fig. 29.

In the table programme, trips in the top two slots of the control slide (Fig. 29) determine the table positions at which the table motion ceases and the head programme starts. The next four slots control rapid and normal feeds in both directions. The feed rates for both head and table are infinitely variable and are set on calibrated dials. Fig. 30 shows how the control slide can easily be removed and retained for subsequent batches, thus reducing the set-up time even further, although increasing capital and storage costs for control slides.

The spindle is driven by a d.c. motor fed from a normal 3-phase supply and is controlled electronically so as to provide a steplessly variable speed range from either 50 to 1400 rpm or 200 to 2800 rpm. Provision is made for automatically stopping the spindle motor during rapid traverse of either the head or table, so as to prevent scoring the workpiece. This has the additional advantage, that if, at the end of a cycle, the table is returned to one of the two end positions at rapid traverse, the spindle motor is already stationary, and re-loading can safely commence immediately.

The electronic equipment for the control of spindle speed is contained in a drawer which pulls out from the back of the machine pedestal. The only glass valves used are two thyratrons which are easily changed and have, in any case, a guaranteed life of 5000 hours. The table and head motions are hydraulically powered, the rapid approaches being at a rate independent of the normal feed. The table can be stopped in either direction of movement by means of an adjustable dead-stop and, if required, reversal may be delayed, i.e., the table can be made to dwell for a preset time before reversing. Since, during this dwell, the table is held against the stop under hydraulic pressure, a very accurate reversal point is achieved. The Centec 3R programme-controlled machine is illustrated in Fig. 31.

Fig. 31. The Centec 3R programme-controlled milling machine.
(Courtesy of Centec Machine Tools Ltd.)

One of the most useful accessories for the Centec machines is a small auto-pneumatic indexing table, available in diameters of either 6 or 8 in. The indexing time of this table is less than one second per station, and it can be used for such purposes as milling multiple faces on a component, rapid loading of small components while the work cycle proceeds, etc. The standard table will index through 30, 60, 90, 120, or 180 deg. merely by push-button control, and indexing can be automatically synchronized with table movement. However, even

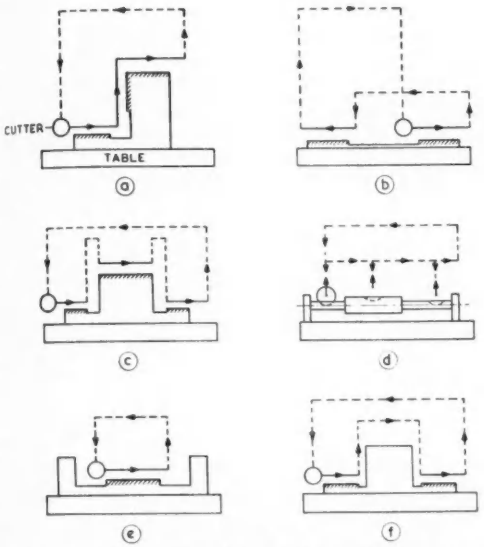


Fig. 32. Some programmes obtainable with the Centec system, showing (a) horizontal and vertical milling; (b) pendulum milling; (c) milling in three planes; (d) key-sinking; (e) milling between obstructions, and (f) milling over an obstruction.

without this accessory, there are many applications for a milling machine with head control and, in Fig. 32, some typical programmes with this system are shown.

A machine with somewhat similar potentialities is the F58 milling machine, made in Switzerland by SAFAG A.G. The head programme is not quite as versatile as in the Centec, but copying is included in the programme.

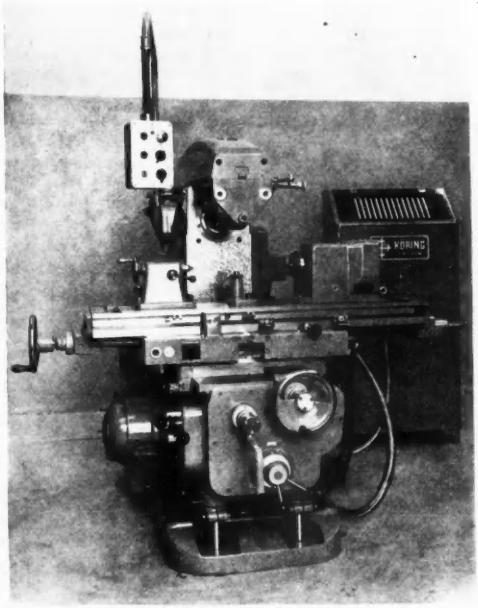


Fig. 33. The Köpings UF-10 programme-controlled milling machine and its control cabinet.
(Courtesy of Köpings Mekaniska Verkstads AB)

In Sweden, Köpings Mekaniska Verkstads AB has taken the opportunity afforded by recent radical re-design of their UF–10 universal milling machine, to offer it with programme control, if required. Table rise and fall is actuated by a pneumatic-hydraulic system in which a spring-loaded electromagnetic valve admits air to a booster actuating the oil cylinder for raising the table. Another valve setting releases the air in the booster, and the table is lowered. Table motion is terminated in its upper and lower positions by contacting limit-switches. Automatic control in this system extends to the dividing head. When each operation of an indexing cycle has been completed, the indexing pin is retracted electro-magnetically, closing a limit-switch which starts the driving motor for the indexing head. A push-button is provided for manual operation.

All the electrical control equipment is contained in the separate control cabinet seen at the right-hand side of Fig. 33. The programming push-button panel is placed on the top face of the cabinet and can be covered with a safety-glass panel when not in use. The main switch and the control-cabinet switch are mounted on the front of the cabinet. The table is provided with a change-over switch for manual, semi-automatic, and automatic operation, and with push-buttons for starting and stopping the cycle. A change-over switch and push-buttons for manual operation of the machine are also mounted on a swivelling pendant for easier control. The spindle motor is reversible and has a direct-current brake. When operated manually, the direction of table movement is selected by means of a lever which actuates hydraulic valves in the knee. When working automatically, the valves are actuated electro-magnetically.

The control circuit works at a rectified d.c. voltage of 24 V, and all components are of the plug-in type to facilitate replacement. The principal item in the programming equipment is a 12-pole, 15-way rotary stepping switch; the 15 ways provide a zero position and 14 working stages in the cycle, while the 12 poles permit up to twelve functions to be controlled (in the case of the UF–10 machine, only eight functions are controlled, and there are thus four blank poles). The contacts are connected in series with relay circuits and the push-button contacts. The relay circuits are intended for the functions to be controlled, i.e., table movement (left and right) at rapid traverse or normal feed rates, spindle rotation, indexing of the dividing head, movement of the knee (up or down), intermediate stop, and end of cycle. A relay for some definite operation in a given stage of the cycle will operate only if the contacts of the corresponding push-button are closed when the stepping switch reaches that stage of the cycle. The stepping switch moves one step forward at the end of each stage, the solenoid circuit of the switch being actuated by an electrical impulse generated when the relevant adjustable trip on the table closes a micro-switch on the knee. The push-buttons are of the type in which the first depression closes the contacts, while the second releases them again.

In Germany, Ludw. Loewe & Co. A.G. have developed several systems of automatic control, commencing with the simplest sequence of operations which could be called a programme (cutting stroke at normal feed followed by return stroke at rapid traverse). The latest development of this company is in connection with their FS 4 vertical milling machine (Fig. 34). One interesting feature of this machine is the arrangement of the milling head,

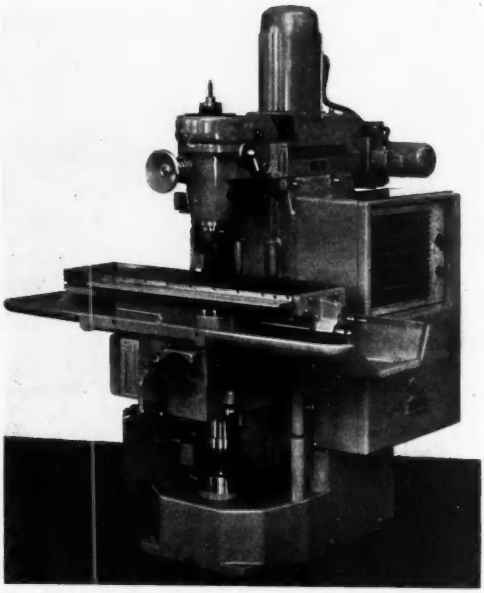


Fig. 34. The Loewe FS-4 programme-controlled vertical milling machine.
(Courtesy of Ludw. Loewe & Co. A.G.)

which, instead of being an integral part of the column, is, in fact, mounted on transverse slide-ways on top of the column. Since the milling head, and hence the spindle, can now be moved transversely, the transverse motion of the table is superfluous, and this fact has enabled the company to adopt a much simpler table and knee design. The spindle is driven by a pole-changing motor through Vee-belts and, if very low speeds are required, these can be obtained by means of a reduction gear.

The table can be moved in a longitudinal direction either manually or under power, using an electric motor and change-gears, adjustable dogs and micro-switches controlling the extent of movement. The knee can be raised and lowered manually or hydraulically, the latter method giving an infinitely variable feed rate. The programme is set on a "preselection panel" having 20 columns of holes (stages in the cycle) and 16 rows (functions to be controlled). Longitudinal, transverse, and vertical relative movements between table and cutter can be programmed, and longitudinal movement can also take place at rapid traverse rate. A punched card can be used to facilitate setting the programme.

The FB 40V vertical milling machine, manufactured in Czechoslovakia and marketed by Strojexport, has been designed to operate either with programme control or numerical control. When functioning as a programme-controlled machine, movable dogs or contacts are set

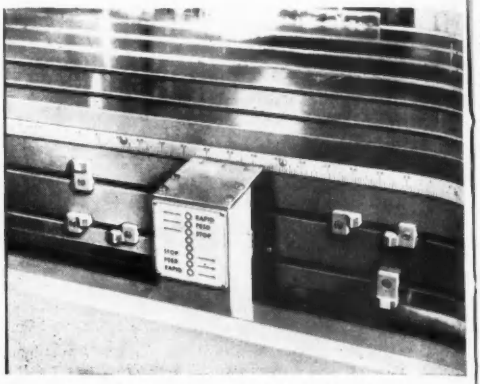


Fig. 35. The selective trips of the "Dial-a-Matic" programme-control system.
(Courtesy of Kearney & Trecker Corporation)

along each of the axes at points where a change of feed is required. This enables a fairly complex cycle to be executed, and it has been considered that the use of punched tape is justified as the means of conveying the numerical information to the machine. This punched tape is divided into blocks of standard length, each block containing the information concerning the direction of movement and feed rate (rapid, normal, or slow). As each dog is passed, closing of the contacts sends a signal to the tape reader, causing the next block of information to be read.

One of the surprising features of programme-controlled machine tools, as distinct from numerically-controlled machine tools, is the limited interest which appears to have been shown by American manufacturers. One notable exception is the Kearney & Trecker Corporation, of Milwaukee, who have followed up their extensive programme of development in the field of numerical control with a programme-controlled system for their bed-type production milling machines (simplex and duplex). This system is marketed under the name of "Dial-a-Matic". One interesting feature of this system is that the trips are not simple on-off devices but are selective and fulfil one of three functions, i.e., to initiate a traverse at rapid or normal feed rate or to stop the

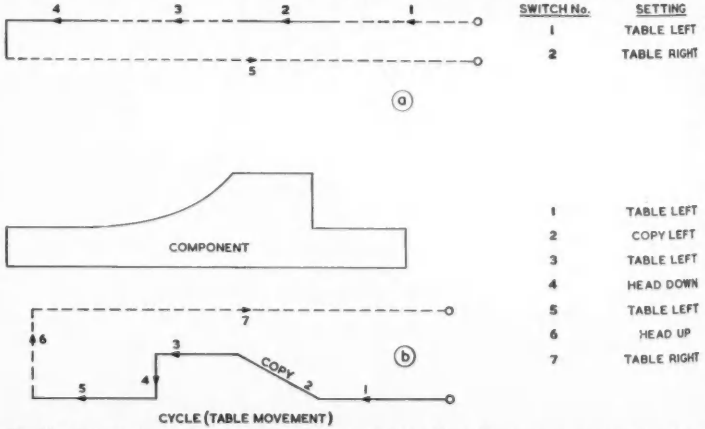


Fig. 36. Two typical cycles obtainable with the "Dial-a-Matic" programme-control system.

moving element (Fig. 35). This means that one ten-way switch is sufficient for setting up each stage in the production cycle; for example, the cycle shown in Fig. 36a requires the setting of only two switches, though it contains five distinct elements, i.e., two normal feeds and three rapid traverses. The control panel carries ten switches, and it is thus clear that even a quite complex programme is not likely to exceed the facilities provided.

The basic machine has four live positions on the control switches, i.e., cycle reset, cycle stop, table right, and table left. If automatic quill retraction is provided, two further live positions are needed (simplex quill in and out). Further optional additions are automatic control of movement of the spindle head (up and down) and tracer control (movements to right and left), these taking up the remaining four positions on the switch. Fig. 36b shows a more complex cycle, in which tracer control is incorporated.

PROGRAMME-CONTROLLED BORING MACHINES

In Switzerland, Dixi S.A. have converted their No. 75 series of horizontal boring machines to semi-automatic operation. These are typical of the type of boring machine with two positioning movements of the table (perpendicular to one another) and a feed motion of the boring tool. The main requirement in this case is fairly simple in conception, although not so easy to achieve in practice, i.e., that the table must move through a succession of positions and be accurately located at each; furthermore, after each location, the boring operation must be achieved, and this may or may not involve accurate depth setting.

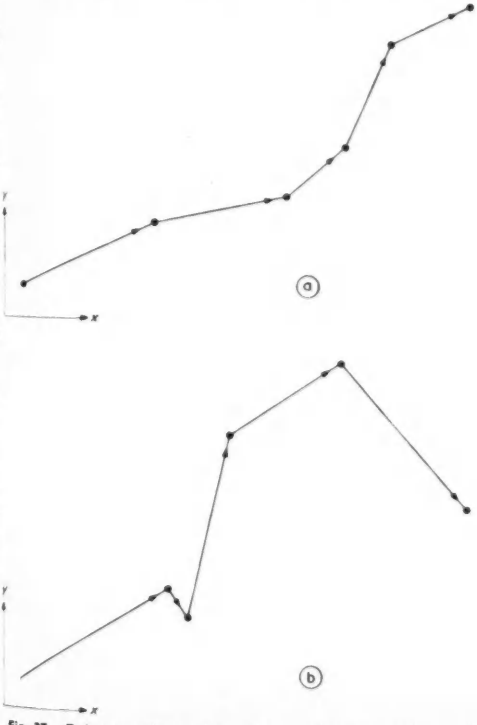


Fig. 37. Point-to-point cycles which are (a) progressive, and (b) retrogressive, in their x-y relationships.

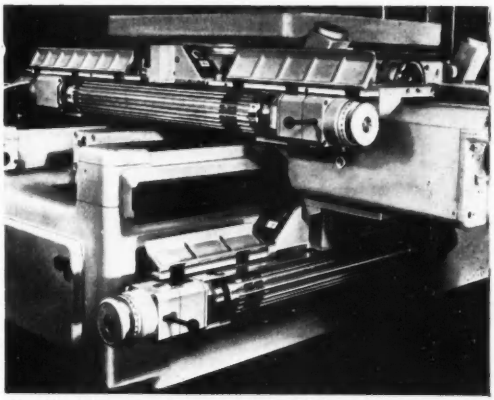


Fig. 38. The control drums of the Dixi programme-control system.

(Courtesy of Dixi S.A.)

As with the systems described in connection with lathes and milling machines, the motion of the moving element (table or tool) must be stopped when the desired location has been reached. There are two fundamental differences, however, between lathes and milling machines on the one hand and accurate co-ordinate boring machines on the other. In the first place, accuracy requirements demand some better positional control than a mechanical stop or dog and, in the second place, the idea, accepted for other machine tools, of a number of stops arranged along a single slot is quite unrealistic. Since stops or dogs are not selective (at least in their simple form), such an arrangement would only work if both x and y components increased constantly for successive locations, as shown in Fig. 37a. If, with the cycle planned to give a constantly increasing x component, some of the successive changes in the y component are negative, as in Fig. 37b, then such a cycle cannot be performed, clearly placing a severe restriction on the components which can be produced with such a system.

The way in which Dixi S.A. have chosen to eliminate this difficulty is to employ, for each movement to be controlled, a drum with a number of longitudinal slots equally spaced around its periphery. A control block in each slot is positioned according to the displacement required, and the drum is indexed to the next slot after positioning is complete. The question of how many slots to employ is clearly a compromise between the inordinately high cost of too large a number of slots and the limited utility if too few slots are available. In this case, the compromise has been settled by using 24 slots. The control drums for the longitudinal and transverse movements of the table can be seen in Fig. 38. With regard to the first difficulty, i.e., that of accurate location, the Dixi system employs a capacitive measuring head, instead of a mechanical trip. In addition to improved accuracy, there is no actual contact between the measuring head and the control block, so that wear is eliminated. The control blocks must still be set, and this is effected by first setting the table in the desired position, using the normal optical system; then, for the slot lying directly below each measuring head, the control block is moved until it is accurately located with respect to the head, this

being indicated by a null reading on a micro-ammeter connected in the balancing circuit of the head, one scale division of the micro-ammeter corresponding to 50 micro-inches.

When used with its automatic cycle, the head controls a double-acting magnetic valve which initiates movement of the table at rapid traverse and then slows it down quickly as the control block approaches the measuring head. Final positioning is accomplished by an oscillatory movement about the desired position. Should it be necessary to pick up a previously bored hole, this can be effected with a dial-gauge centring attachment. The control system can be synchronized, since the position of the drum can be adjusted slightly in an axial direction until the micro-ammeter reads zero, automatically bringing all other positions to their correct relationship.

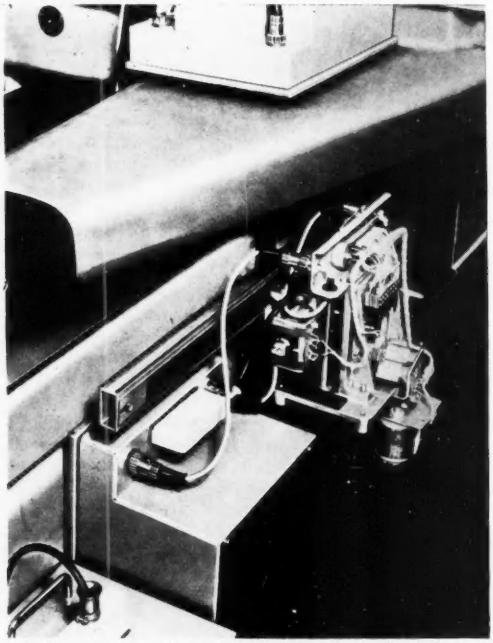


Fig. 39. The magnetic tape and reading head of a Hermann Kolb programme-controlled co-ordinate jig-boring machine. *(Courtesy of Herman Kolb Maschinenfabrik A.G.)*

The co-ordinate jig borers made in Germany by Hermann Kolb G.m.b.H. are equipped with a programme-controlled system using magnetic tapes, a magnetic tape moving past a reading head for each axis to be controlled. A magnetic impulse recorded on the tape is used to stop the movement of one element relative to another and, if desired, a second reading head can be positioned a short distance in front of the other in order to provide the signal for a slow-down prior to stopping. The difficulties referred to in the previous paragraphs still obtain with this system, since the method of position indication is no different in principle from the ordinary micro-switch. The Kolb system, however, is provided with a form of plug-board (called a co-ordinator), in which the correct synchronization between x and y values is achieved by setting plugs.

Fig. 39 shows a magnetic tape and reading head in position on one of these jig borers.

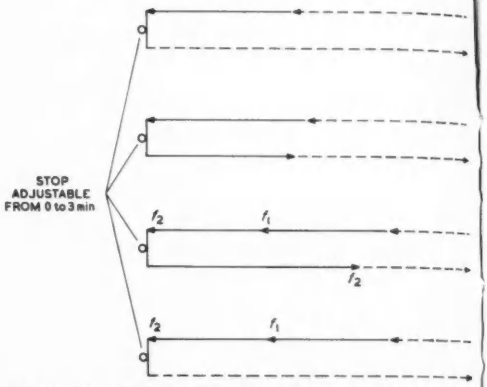


Fig. 40. The standard cycles of the Cimat programme-control system.

The other type of boring machine is that which functions mainly as a boring and facing machine; if this kind of machine is to be programme-controlled, it requires standard cycles similar to those for the longitudinal movement of a milling-machine table. The standard cycles for the "Cimatic" series of boring machines made in Italy by Cimat s.p.a. are shown in Fig. 40, and it will be noted that, at the end of its travel, the table can return immediately or can remain at rest for a predetermined period of time in the range between 0 and 3 minutes. Also, during the machining part of the cycle, the feed rate can be changed automatically from one value f_1 to another value f_2. These boring machines are hydraulically operated, control being effected by means of simple change levers mounted in four panels located in a convenient position for the operator.

The limits of movement of the tool-holder table are controlled by cams and pawls. The reversing pawls are adjusted coarsely by hand and finely by means of a micrometer screw. Table feed is regulated by adjustable cams acting on vertical tappets. The cams are of double thickness and, by adjusting one thickness in relation to the other, it is possible to vary their field of action on the relevant tappets. This adjustment of thickness is facilitated by a graduated scale.

PROGRAMME-CONTROLLED GEAR-HOBBING AND GEAR-GRINDING MACHINES

Gear-hobbing requires, in the main, simple rectangular programmes or modifications thereof. Fig. 41 shows the programme cycles of the gear-hobbing machines made in Germany by Maschinenfabrik Lorenz A.G., Fig. 41a referring to axial on-cut, and Fig. 41b to radial on-cut. It will be seen that a single or double-cut cycle can be selected, and, in addition to the programmes shown, which are for a single gear blank, there are corresponding cycles for two gear blanks mounted adjacently on one spindle, these being called respectively "simple programmes" and "succession programmes". If all these facilities are provided, the system is termed "universal cycle control", but there is a simpler form called "normal cycle control" which is limited to the single-cut cycles. Both systems include a hobbing-out device for cutting free the tooth profile in the radial and axial hobbing of spur gears.

In normal cycle control, the programmes are pre-

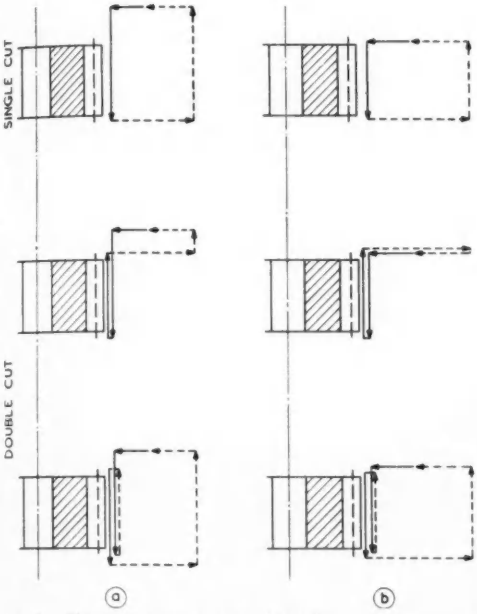


Fig. 41. The programme cycles of the Lorenz programme-controlled gear-hobbing machine (a) for axial on-cut, and (b) for radial on-cut.

selected by means of a multi-way switch but, in universal cycle control, the automatic sequence of operations is controlled by punched cards which are inserted into a slot in the distributor casing. Many batches, although small in size, no doubt have been produced before, and the punched card for a particular batch will often be available in a "library" of programme cards. Only one card is required for both down-cut and up-cut hobbing, since feed direction can be preselected by means of a switch. Also, any machine movement which is included in the automatic cycle and which is not required in a particular programme can be eliminated from the programme by the use of selector switches. Although not specifically part of programme control, it is interesting to note that the Lorenz gear-hobbing machine can be provided with an automatic work-loading turret.

In the U.S.A., Barber-Colman have applied a simple system of programme control to their Nos. 6–10 and 16–16 hobbing machines with the object of improving production times for small batches. The three cycles used are the plunge-approach cycle, the square cycle, and the plunge cycle. With regard to the plunge-approach cycle (Fig. 42a), since approach time frequently represents a large part of the total production time for a hobbed gear, this cycle has been designed to reduce the approach time to a minimum. The horizontal feed is engaged at the commencement of the cycle, so that the required helix angle is cut. The work feeds vertically into the hob with a feed rate which changes continuously from a high value at the beginning of the cut to a low value as the hob reaches full depth, vertical feed and rapid traverse being controlled by a vertical-feed cam. With the plunge-approach cycle, larger hobs having more flutes and more starts can be used without an increase in approach time. The larger number of flutes used permits greater accuracy and better production, the latter benefit being normally enhanced by an increase in the number of starts. The cycle is also advantageous in the hobbing of blind worms and gears.

The square cycle (Fig. 42b) is the automatic version of the conventional hobbing cycle and can be programmed with down-cut or up-cut in either direction.

The plunge cycle (Fig. 42c) provides an automatic vertical feed for cutting worm-gears.

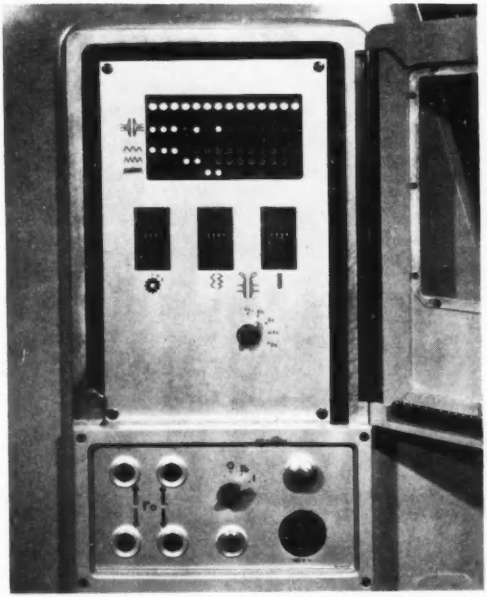
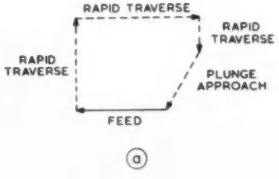


Fig. 43. The control panel of the MAAG programme-control system.
(Courtesy of the MAAG Gear Wheel Co. Ltd.)

A representative gear-grinding machine fitted with programme control is the HSP 80 machine, made in Switzerland by MAAG, which has a maximum blank capacity of about 32 in. and covers the range from 1·7 to 12·7 D.P. (15 to 2 mm module). The involute shape is generated by means of the usual pitch-block and steel tapes, the familiar pair of saucer-shaped wheels being used for the grinding operation. Wear-compensating devices, operating to within 0·00005 in., are incorporated.



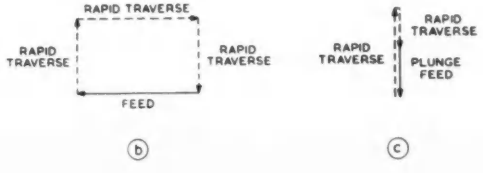


Fig. 42. The standard cycles of the Barber-Colman programme-controlled gear-hobbing machine, showing (a) the plunge-approach cycle, (b) the square cycle, and (c) the plunge cycle.

Automatic control of this machine is complete, inasmuch as no attention is required during the grinding operation, the cycle being set by means of a push-button panel (Fig. 43). Contacts are provided for a maximum of 14 revolutions of the workpiece and, for each revolution, the amount of cut and one of three feed rates can be selected on the push-button panel. The panel also carries facilities for setting the indexing movement and dressing the grinding wheels. For the latter function, from 1 to 5 motions of the diamond may be selected, and a definite amount of wheel material can be removed after a predetermined number of teeth have been ground.

EXAMPLES OF THE APPLICATION OF PROGRAMME CONTROL

The potentialities and limitations of programme control have already been discussed on general lines, and, now that many of the available systems have been considered in more detail, it is perhaps apposite to look at some typical examples of components machined under programme control, so as to assist in the assessment of the field of application for programme-controlled machine tools.

Example 1

Fig. 44 shows a stepped shaft which is to be machined from a 50-tsi steel bar, 3 in. in diameter. This can be produced on a programme-controlled turret lathe, as follows:—

(a) Feeding the stock to a stop held in the first turret station.
(b) Rough-turning the length to the right of shoulder *A*, using a tool in the second station.
(c) Making a second roughing cut and a finishing cut on diameter (1), using tools in the third and fourth turret stations.
(d) Centre-drilling the end of the bar (fifth station) and inserting a running centre (sixth station).
(e) Rough and finish copy-turning the remaining length of the shaft.

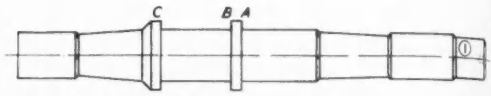


Fig. 44. Production of a stepped shaft on a programme-controlled lathe.

(f) Squaring up the shoulders *A*, *B*, and *C*.
(g) Parting off.

For operations (e) to (g) inclusive, the tools can be held in a square indexable tool-post or in cross-slides.

Clearly, the only competitive method worth serious consideration is production in a conventional copying lathe; it should be remembered, however, that many companies which could economically justify a programme-controlled general-purpose machine tool could not consider a more special-purpose machine such as a copying lathe. Furthermore, in this particular component, the square shoulders at *A*, *B*, and *C* could present difficulties with a copying lathe.

Example 2

Fig. 45 shows a sectional view of one half of a cylinder cover, together with the suggested schedule for machining the shaded surfaces, using a vertical turret lathe.

Surfaces 1–2, 4–5, and 7–8 are faced from turret station I, movements 0–1, 2–3–4, 5–6–7, and 8–9–10 being performed with rapid traverse. At point 10, the turret is indexed to station II, and the copying attachment switched in. The profile 10–11 is then copy-turned, and the turret is retracted rapidly (11–12). The copying attachment is switched out after point 11, and at point 12 the turret is indexed to station III, where, after a rapid feed to point 13, profile 13–14–15–16 is turned as a stepped programme. The settings of the limit-switches are also shown in Fig. 45.

Example 3

Fig. 46 shows a component which is to be milled over the light area, the whole of which lies in the same plane, so that the operation can be completed in one setting on a

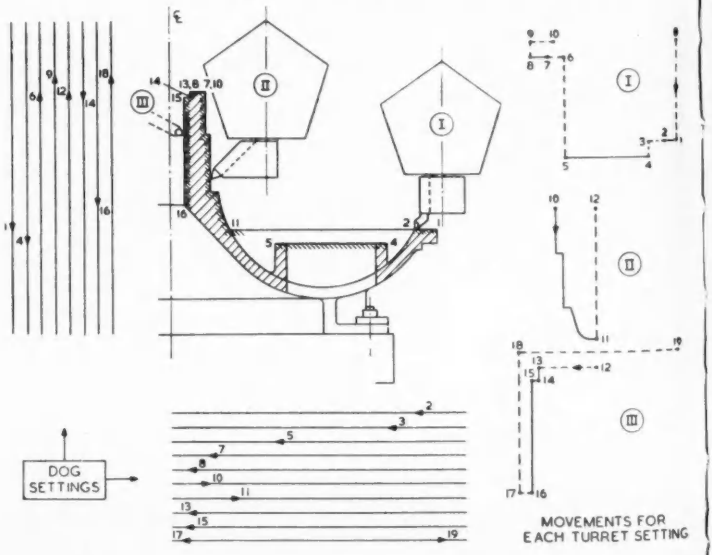


Fig. 45. Production of one-half of a cylinder cover on a programme-controlled vertical turret lathe.

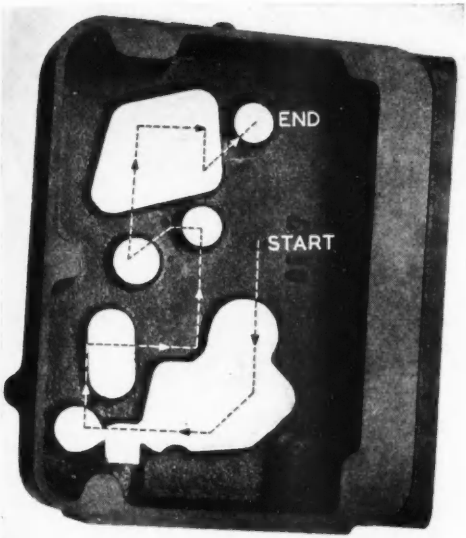


Fig. 46. Milling a component over a specific area (light) and the programmed cutter path.

vertical milling machine, using an end-mill. This programme is quite easily effected, especially on a machine in which a 45-deg. movement can be obtained by synchronizing two main feeds, and the actual cutter path shown in Fig. 46 has been drawn on this assumption. This particular component is a good example of one which can benefit, in batch production as distinct from one-off production, by programme control and can still be clearly more economical than numerical control. This is perhaps shown to even greater advantage by the component illustrated in Fig. 47, where the machine can be set up economically for quite small batches, using programme control.

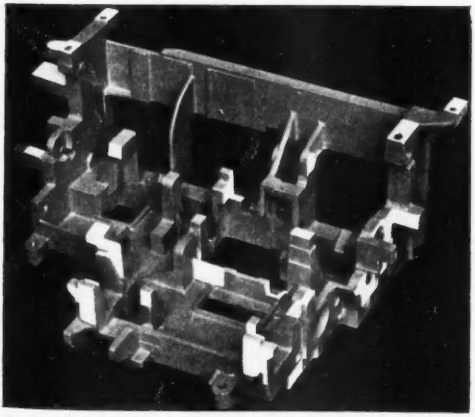


Fig. 47. A fairly complex component illustrating the usefulness of programme control.

No examples have been given for boring or gear-cutting machines, since they are, by the nature of their work, restricted to simple standard cycles. It should, however, be understood that this does not detract from their usefulness.

ACKNOWLEDGMENTS

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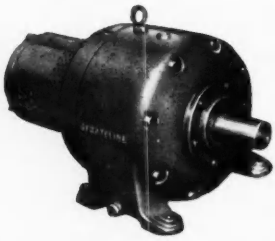

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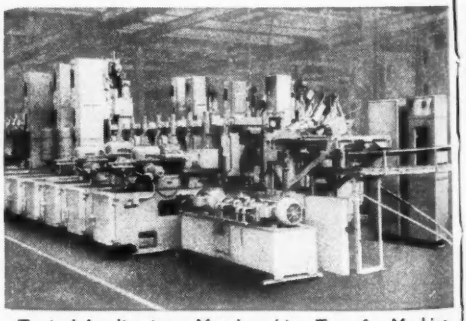

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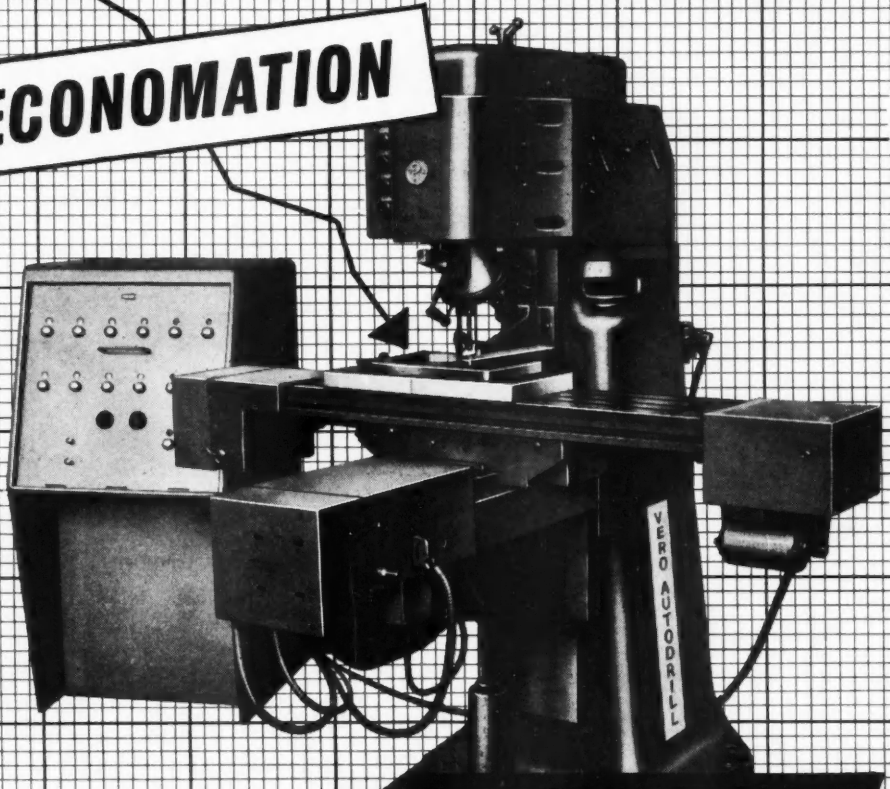

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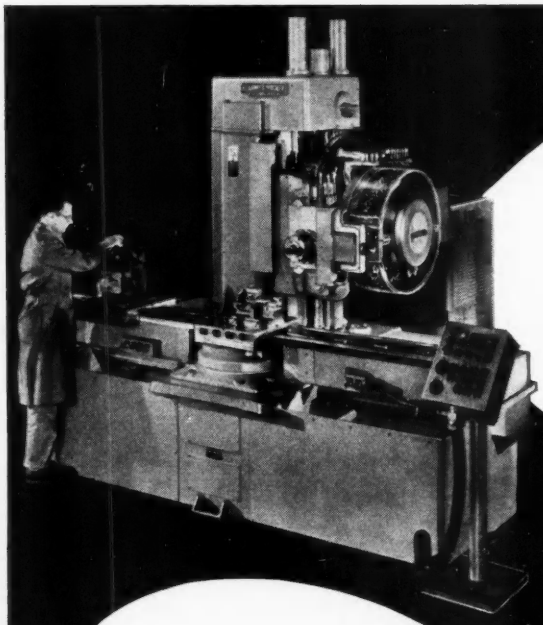

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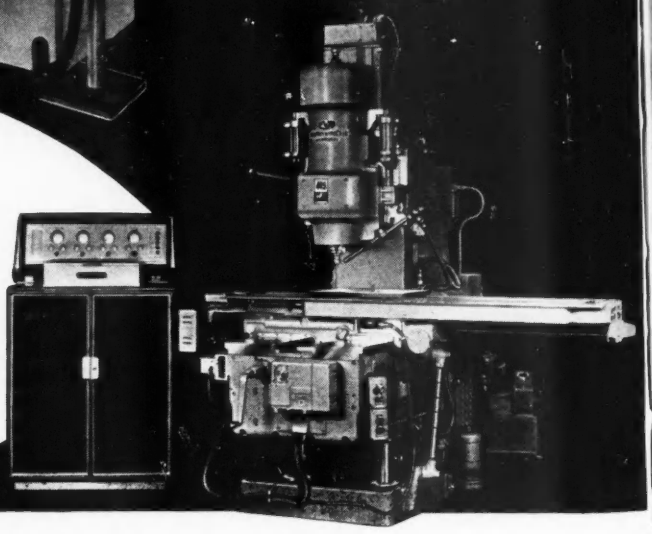

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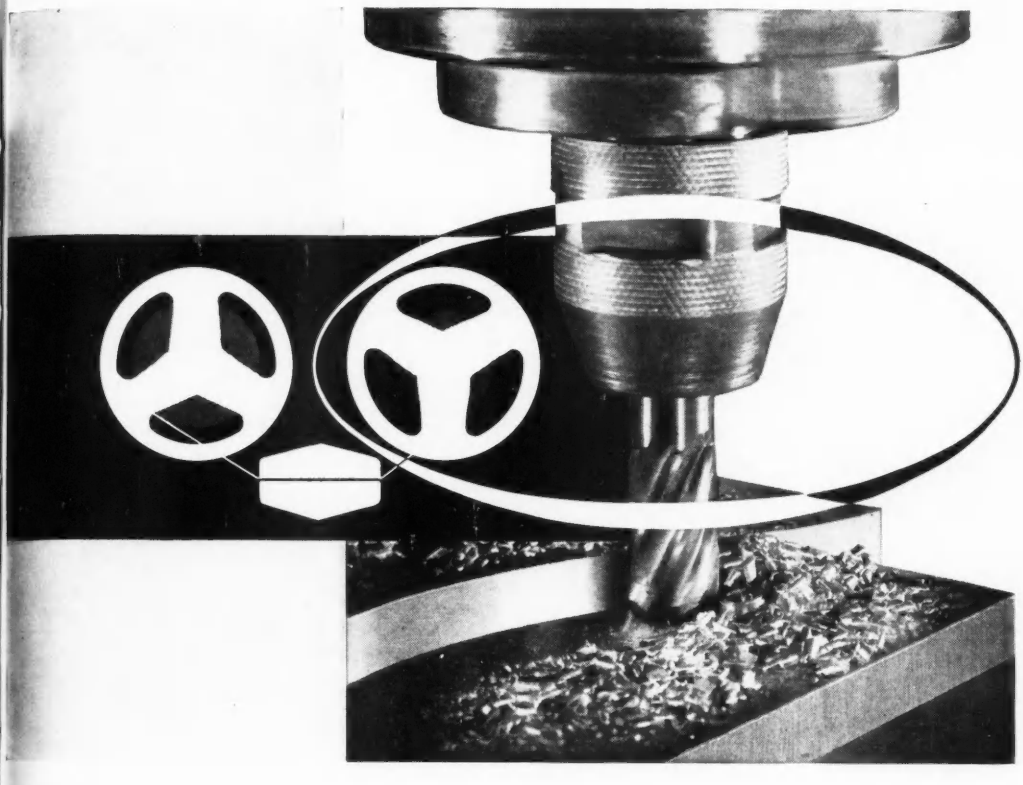

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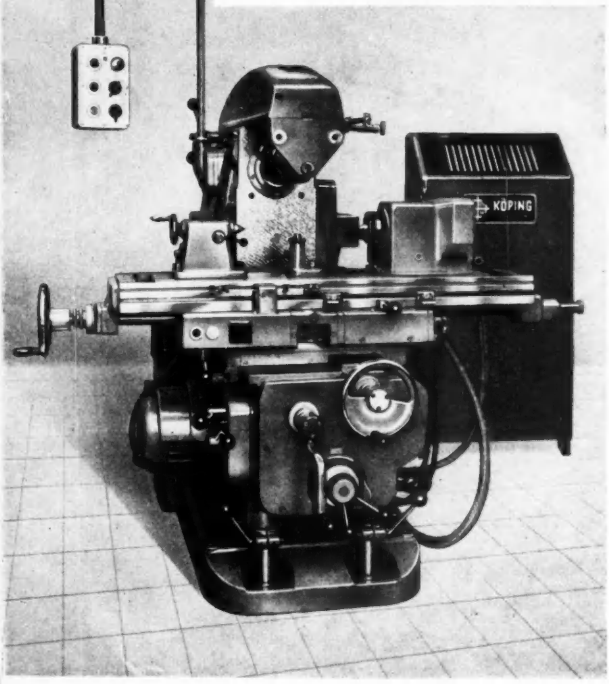

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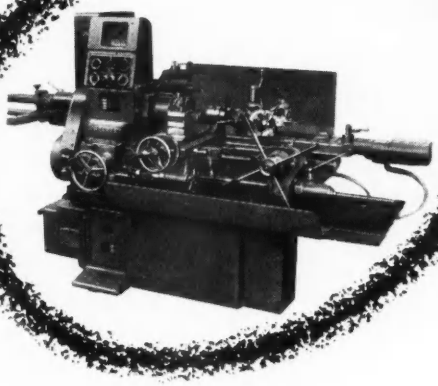

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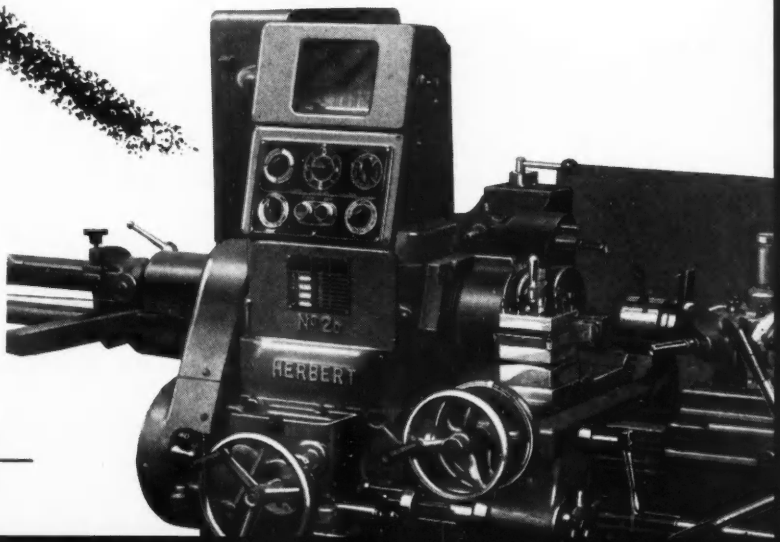

The programme-control system on this 1½" dia. bar or 9" swing capstan lathe, automatically selects speed changes and starts, reverses and stops the spindle, as required. Indexing the turret automatically selects the pre-set conditions for machining from the next turret face.

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A World Review of DESIGN & PRODUCTION — RESEARCH & DEVELOPMENT

VOL. XXI No. 6 JUNE, 1960

Standardized Mechanical Components for Servomechanisms

By M. D. HULL, Assoc.Brit.I.R.E.*

In this article, the problems encountered in the construction of servomechanisms for development purposes are discussed, and the advantages of using standardized mechanical components are pointed out. In addition, a range of suitable components is described, together with factors affecting their design.

IN the construction of servo-systems, it is usually necessary to accept the most suitable electrical element available for the purpose, the choice being governed first by achieving the desired characteristics and then by cost. Thus, a search through manufacturers' data sheets may reveal a synchro of the desired kind and, after price comparisons have been made, the appropriate item is selected, or alternatively, a compromise is reached. By electrically interconnecting various electrical servo components on the bench, and applying an input signal, it is possible to obtain some idea of the future performance of the arrangement. Unfortunately, the stage now reached has resulted in a mass of tangled leads with power supplies, phase-sensitive valve voltmeters, amplifiers, and synchros all mixed up together on the bench.

Problems of Construction

For the mechanical interconnection of the electrical elements, two courses are now open to the engineer, i.e., he can call on the Drawing Office to produce a design for mounting the essential electrical parts, or he himself can design a suitable mounting which the model shop can produce. It is reasonable to suppose that the electrical designer will be able to make a more satisfactory attempt at the mechanical design, in which he is not a specialist, than will be the mechanical designer to produce an electrical servo. However, the mechanical designer will probably be horrified at the sketch the electrical engineer produces for his requirements, and in extreme cases the model shop will discreetly point out that it is impossible to make it. Normally, close liaison between electrical and mechanical designers takes place, and it becomes essential at a later stage of development, when the choice of gearing is involved between the load and the servo-motor and other electrical elements. It does not, however, usually take place at the beginning of development, when only a simple solid mounting is necessary for the electrical elements during initial measurements, and the servo-engineer then relies on his own intelligence to design something suitable.

After initial measurements on the preliminary chassis have been made, it is invariably necessary to design suitable gearing to connect a dummy load to the servo-motor and to link suitable feedback generators. Unlike the exchange of a resistor on a tag-board for one of a different value, which can be completed in under a minute with a soldering iron, the interchange of a gear-train may take many hours, because the characteristics of mechanical parts of this nature are not only a function of their own dimensions, but also of the dimensional relationships existing between each other. In the case of electrical components, their own mechanical dimensions control their particular electrical characteristics, and direct dimensional relationships between them are of little consequence, since it is only the electrical characteristics, owing to their individual mechanical dimensions, that must bear the necessary relationships. No electrical engineer would consider dissecting a carbon-rod type of fixed resistor and then file away the carbon to change its resistance value, but would change the whole component. In effect, this is what the servo-engineer has to do to his gear-train, unless he is lucky enough to have a very large variety of gearboxes readily available for trial, in which case he can also make the required change as a complete mechanical component.

The requirements for mechanical design have now reached a stage which has outweighed the electronic design. No longer will a simple mounting suffice, and, even in the development stage, precision mechanisms are required. Thus, the simple hole in a chassis is no longer satisfactory, aligned holes for shafts and bearings are needed, and accurate centre distances for gears must be achieved. In fact, nothing less than production standards are forced on development. If the inertia of a gear proves too high, or a change in gear ratio proves desirable, then the parts of the gear-train must be dismantled and the alternative parts fitted. Should different diameters in gears be involved in the modification, then new centre distances apply, and the whole gear-train might just as well be constructed afresh.

The time and cost involved in producing precision mechanical assemblies, each time some improvement is felt desirable, place the onus on the engineer to be right first time with no further alterations. Surely, this is wrong. No management would impose such serious restrictions on development, but would hope for a good design, truly developed stage by stage by calculation and measurement. Modification is all part of development in the search for something really good. However,

* *Technical Director, Pioneer Designs Limited, Servokits Division, East Molesey, Surrey.*

all the time development costs are continually rising, and each new gearbox can add hundreds of pounds to a project. The time to produce these "one-off" jobs for development, spread over the laboratory, the drawing office, and the model shop, is very considerable and, even under the best conditions, a delay of three or four weeks may not be unusual before work can continue on the bench. Certainly, then, it is no wonder that control equipment involving servomechanisms is expensive.

Standardized Mechanical Components

The solution to most of these problems is found in the provision of standardized mechanical components in the same way as electronic components have become standardized. By standardization of the frame sizes of synchros, manufacturers have paved the way for standardized mountings on which the synchros hang. Hangers, as these mountings are named, together with a wide range of other standardized mechanical components, have been designed by the author for use in the development of servomechanisms and other similar mechanical assemblies.

Many factors have had to be taken into account in the design of the various components, i.e., accuracy, ease of assembly and dismantling, the production of components of fully known characteristics, shaft sizes in common use, choice of hardware, absence of special tools, and cost. To these were added the problems of the advisability of producing a particular component based on its anticipated usefulness and, moreover, how to offer such a miscellaneous collection of parts for sale.

During the development of their own servomechanisms, certain manufacturers have designed general-purpose mechanical components for use within the firm. In some cases the success of these parts has encouraged an enterprising management to manufacture the components for sale in the form of kits. There are two distinct classes of products in existence, i.e., those conforming to normal engineering standards, and those of high precision. There are undoubtedly some occasions when high precision remains essential, but the range of components designed by the author aims at the former class, in order to keep development and production costs down and to reduce the tendency towards the over-precision which has arisen in recent years.

Platforms

By far the grestest stumbling-block in constructing a servomechanism is to find a suitable mounting plate on which to attach the electrical components. The plate may have to carry a considerable weight of parts, but must not readily bend or be capable of being distorted. Thus, if accurate gear-trains are to be used, it must not warp, or the gears will bind or have increased backlash. To enable parts to be bolted to it, both sides of the plate must be readily accessible, and a wide variety of mounting positions provided. Also, it must be inexpensive.

This mechanical component is called a platform and, since it forms the "chassis" for the assembly of synchros and gear-trains, its design is governed by the class of accuracy desired in the prototype model. Many different arrangements for slotting the platform have been used, and it appears that most manufacturers regard this as a means of identity from an aesthetic viewpoint, rather than one of technical utility. For example, one design uses plain holes at fixed centre distances, whereas staggered slots running diagonally across the platform are preferred in another, though most platforms favour a slot width of $\frac{1}{4}$ in. Both aluminium and steel have been used as the material and, in the high-precision class, an aluminium casting is favoured. Production costs for this type of platform are naturally high, to maintain a high standard of flatness over a large area, and such a platform needs to be treated with considerable respect in use.

The sizes of platforms available vary considerably, but the majority measure less than 18 × 12 in. Platforms should be available in two sizes, with one lateral dimension in common, permitting "double-decking" of platforms by the use of extension studs to join consecutive lengths of supporting pillars. Provision should also be made for joining together a number of platforms in the same plane to provide for special circumstances where an "outsize" platform is necessary.

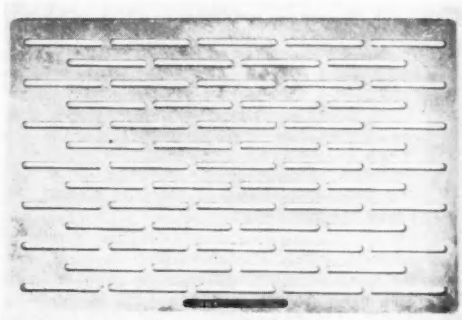

Fig. 1. A typical platform for mounting servomechanisms

The above design criteria have been incorporated into an inexpensive platform which has proved completely satisfactory for general use. A typical platform is shown in Fig. 1, and consists of a mild-steel plate, $\frac{3}{16}$ in. thick, punched with staggered rows of slots, each slot 3 in. long and $\frac{1}{4}$ in. wide, running laterally along the plate. One side is ground flat to provide an accurate mounting face, and the other side is similarly ground to stress-relieve the material, thus avoiding distortion. The platform, which is cadmium-plated, can be supported on four pillars to give easy access to the underneath side for attachment of hangers and other parts which may be bolted to it. These pillars are fitted with small neoprene feet to prevent assemblies sliding around on the bench.

Mounting of Components

All smaller components fitted to the platform are generally attached by 2 B.A. socket cap-screws, strength and availability being the reasons for this choice. The screws are inserted through the required slots in the platform from the underside and engage with tapped holes in the hangers, pillars, etc., to be attached. The cap-screw has the advantage of a knurled head and can easily be tightened with the fingers during the first trial assembly, slackening of the screws permitting lateral movement of the parts along the length of the slots in the platform for adjustment purposes. Only when the final position of the hangers is found is it necessary to use a wrench key to tighten the screws.

One manufacturer provides wing-headed screws, but the extra cost involved appears to provide little advantage

over a readily available product. In another case, the platform slots are accurately milled to fit T-shaped locating blocks which are intended to maintain parallelism of mounted components, but, because of the clearance in the holes in the blocks through which the clamping screws must pass, the intended accuracy is lost. By far the most practical method of aligning components mounted on the platform is by the use of a simple engineer's square.

Hangers

As these new servo components are intended to be used throughout the development stage of any project, and the services of the Drawing Office called on only for the production drawings, these components should be of standard dimensions to enable draughtsmen rapidly to convert the dimensions of the development prototype to the production drawings. For structural parts such as synchro hangers and shaft hangers, of the types shown in Fig. 2, vital dimensions forming multiples of $\frac{1}{2}$ in. are considered most satisfactory.

(a) (b)

Fig. 2. Two types of component hangers, showing (a) a hanger for mounting a synchro, with an accurately machined bore for accepting the synchro spigot, and (b) a shaft hanger with a needle roller bearing pressed into the hole.

The hangers for electrical elements such as synchros and potentiometers are made of aluminium-alloy angle, $\frac{1}{4}$-in. thick, anodized and dyed black to protect the material and to maintain an attractive appearance despite constant use. A hole for mounting a synchro is accurately bored on one leg of the angle to accept the spigot of the synchro, and the centre distance of this hole from the other leg of the angle, which acts as the foot for attachment to the platform, is accurately maintained to $\pm 0{\cdot}001$ in. A choice of 1·500 or 2·000 in. for this distance is available, but, in the case of components of International Frame Size 23 and over, the 1·500-in. dimension does not apply. The foot is drilled and tapped to accept the 2B.A. socket cap-screws for attaching the hanger to the platform.

Many designs of hanger have appeared, their main differences being in the disposition of the feet, but, in the author's opinion, these designs have little advantage over the simple L-shaped section, and their cost is invariably greater than the type described above. Some manufacturers offer a greater range of centre heights for synchro hangers but, as the size of synchros is internationally standardized, the two different heights of 1·500 and 2·000 in. are sufficient.

To conform to NATO standards, all International Frame Size synchros have their attaching screws and threaded holes cut with Unified threads. This is no longer any cause for concern, as the hangers are tapped UNF to accept the three clamp screws by which the synchro is held to the hanger, and the obtaining of special taps need not be a cause for further delay in development.

Shafts and Bearings

For shafts and bearings, the wide variety of instrument servo work has demanded three individual dimensional systems, which have accordingly been standardized into shaft systems of $\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ in. diameter, their selection depending on the loads involved. Shafts of four different lengths, i.e., 3, 6, 9, and 12 in., are supplied to each system. Shafts are of stainless steel and are accurately ground to $+0{\cdot}0000/-0{\cdot}0003$ in. These limits have been determined by the choice of bearings.

It is interesting to note that the medium-duty system, using shafting of $\frac{3}{16}$-in. diameter, is by far the most popular. The heavy-duty system is next in demand, with a shaft diameter of $\frac{1}{4}$ in. There appears to be little present demand for the $\frac{1}{8}$-in. diameter light-duty system.

Some attempts have been made in the past by certain manufacturers to produce similar standardized mechanical components of a precision nature, but all have suffered from the problems of bearings. Ball-bearing races have been proved to be completely unsatisfactory for the solution of the problems already discussed. One of the aims of producing these components is to ensure rapid interchangeability; for instance, when fitting together a gear-train, the shaft is introduced into the ball race and a reasonable attempt will probably be made, with the aid of a vice and wooden blocks, to press the bearing onto the shaft. If the task proves too lengthy, or little headway is made, the shaft will probably be rubbed down with emery cloth until it fits. A spur gear is then fitted, and finally the bearing for the other end of the shaft is forced on. If the gear is to be changed after tests have been carried out, the whole agonizing process must be repeated in reverse.

For high-precision applications and where assembly time is of little consequence, ball bearings are mostly used but, for normal applications and where time and cost are important, needle roller bearings have been selected as being the most satisfactory, as they do not have an inner ring, so that the difficulties encountered with ball races do not apply. The needles make direct contact with the shaft and the shafts are hardened accordingly. Shaft hangers are drilled to house the bearings, and the bearings are pressed into these bores. When the hangers are attached to the platform in their approximate positions, the shaft can easily be pushed through the bearings. Collars can be fitted on the shaft to restrain axial motion or, if the closed-end type of needle roller bearing is used, nylon or P.T.F.E. balls can be inserted between the end-covers of the bearings and the ends of the shaft.

Gears

In general, the standard of gear-cutting is high but, apart from high-precision applications where the bore of the gear requires reaming out to accept the shaft, most manufacturers lose accuracy when mounting the gear on the shaft, because the time-honoured method of attaching everything of a temporary nature by a grub-screw has been ruthlessly applied in nearly all cases.

The design of spur gears should be decided on grounds of accuracy and cost. It is well known that far too high standards of accuracy are often requested, when a lower-priced product could perform the function just as well. Nevertheless, accuracy should be available and, if this can be obtained at a lower cost, a distinct advantage has

been gained. A gear cut to Class 1 Admiralty Standards costs approximately 30% more than one cut to B.S. 436, Class A. The eccentricity caused by the grub-screw method of mounting a Class 1 gear reduces its effective quality to worse than that of a gear cut to much lower standards but which is correctly mounted. Drilling and pinning defeat the object of rapid interchangeability, and this method should be reserved for production models.

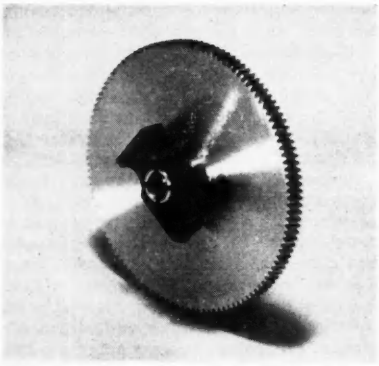

Fig. 3. A split-hub spur gear, showing the hub clamp for attaching the gear to the shaft

A good solution to this problem is to clamp the gears to the shafts and to provide all gears with split hubs, so that they can easily be pushed onto the shafts, the hubs then being surrounded by a low-inertia dynamically balanced hub clamp, specially hardened for springiness. By slackening the clamp screw, a gear can be slid along its shaft to any position in a few seconds. Because no grub-screws are used to secure the gears to the shafts, burrs caused by the points of these screws are absent from the shafts, and easy removal of gears is ensured. A split-hub gear of such a type is shown in Fig. 3. Mitre and ratio bevel gears have been added to the range, and these gears, which are also of the split-hub type, are cut to B.S. 545, Class C.

A special advantage has been discovered in the use of split-hub gears. In a servomechanism, the position of the rotor shaft of an electrical element, such as a synchro relative to its stator, is controlled by an electrical signal proportional to the error in the system. The final setting of the error-computing device in relation to the servomotor providing the driving torque is normally made by rotating the stator of one of the electrical elements, and this may entail lengthy and complex operation if the clamping screws of the synchros are hidden behind other parts. By using a split-hub type of gear on the shaft of the synchro, the hub clamp can be slackened with the synchro energized and the gear rotated on the shaft to produce correct alignment of the driven mechanism relative to the prescribed datum. The clamp screw is then tightened. A loose-fitting gear using a grub-screw would be impractical in this application for reasons of eccentricity, whilst a tight-tolerance bore would not allow sufficient freedom for the synchro shaft to take up its normal energized position. This application of the split-hub gear should reduce considerably the time and expense involved in alignment of position servomechanisms.

A wide range of diametral pitches of gears exists, those generally preferred being 32, 48, 64, 96, and 120 D.P. The tendency towards miniaturization of servomechanisms, particularly in the field of guided missiles, has produced even higher diametral pitches, but, bearing in mind that the teeth of a 200-D.P. gear look like the milled edge of a florin, there is little wonder that their cost is extremely high. In any case, it is practically impossible to produce an accurate tooth form with such high diametral pitches and, contrary to a popular misconception, the quality of the final product deteriorates very rapidly as diametral pitch is increased. It is actually possible to file away a few teeth of a gear under these conditions without even impairing its overall performance.

The diametral pitches which have been selected for the split-hub type of gears are 96 D.P. for light-duty spur gears ($\frac{1}{8}$-in. shaft diameter), 64 D.P. for medium-duty spur gears ($\frac{3}{16}$-in. shaft diameter), 48 D.P. for heavy-duty spur gears ($\frac{1}{4}$-in. shaft diameter), and 32 D.P. for bevel gears. The maximum gear ratio obtainable in each range has been standardized at 5:1.

Little in common exists between various makers on the question of materials but, as this question is directly related to strength and as no heavy loads are involved with instrument gears, brass is a preferred material for gears intended for prototype development. The "standardized" gears are of $\frac{1}{8}$ in. face width, recommended values of torque for 48, 64, and 96 D.P. brass spur gears operating at 1000 rpm being given in Fig. 4. Most manufacturers prefer to use metal gears and supply them in either brass, aluminium alloy, phosphor bronze, or stainless steel, the necessary torque-correction factors to the values given in Fig. 4 being 0·8 for aluminium alloy, 1·2 for phosphor bronze, and 2·5 for stainless steel. Moulded nylon gears, whilst eminently suitable for some applications, are not preferred for servo work, because of their poor tooth form and the extremely high tool costs associated with a producing a large range of gears.

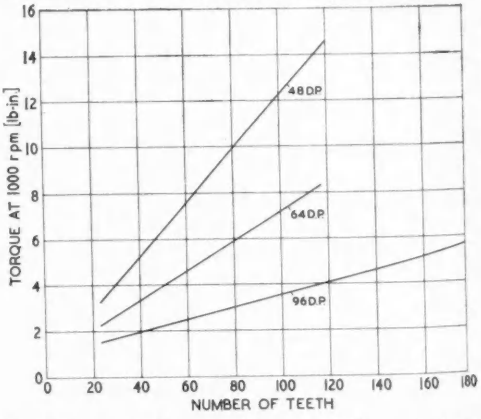

Fig. 4. Recommended values of torque at 1000 rpm for brass spur gears.

To reduce their inertia, some gears are available with lightening holes and, in the high-precision class, at least one manufacturer produces these in aluminium alloy to Admiralty Class 1 standard, but, as the object of producing standardized components is to lessen the number of alternatives rather than to increase it, no lightening holes have been added, enabling a gear of easily calculable inertia to be used for development; lightening holes can be added later, or a change to other materials readily made, for the final product.

Differentials

Both spur-gear and bevel-gear types of differentials are available with interchangeable end gears which, in some cases, are attached by screws and located on spigots of the differential. The bevel-gear type is far simpler than the spur-gear type and is much less expensive to produce.

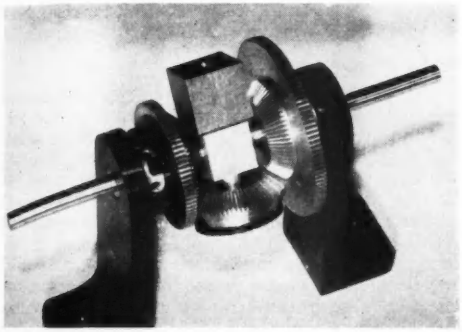

Fig. 5. A bevel-gear differential, with one clamp plate removed for fitting an interchangeable end gear.

The bevel-gear type of differential shown in Fig. 5 is a complete component and uses three brass bevel gears, one of which (the spider gear) is mounted on a shaft at right-angles to the main shaft. The remaining bevel gears have accurately machined hubs on which interchangeable end gears are held in position by removable clamp plates. Precision ball bearings are pressed into the bores of the bevel gears and support them on stainless-steel shafts. Low static friction and lost motion between any two end gears are kept to a minimum by careful design and manufacture. The differential shown in Fig. 5 has one clamp plate removed for fitting an interchangeable 64 D.P. end gear. These interchangeable end gears are available in 48, 64, and 96 D.P., the range of teeth in 64 D.P., for example, being 72, 80, 84, 96, 100, and 120 and catering for popular demand. The output-shaft diameter has been standardized at $\frac{3}{16}$ in. for the same reason.

Fig. 6 shows the differential when two selected end gears have been fitted. The counterbalance block on the spider shaft is adjusted individually on each differential, and the friction clamping exerted by the clamp plates is more than adequate for the intended tooth loading of the end gears.

Components for Torque Measurements

The measurement of servomotor characteristics under varying conditions of load is a necessary feature of performance testing, and it is considered necessary to provide parts to assemble a torque "gallows" for this purpose. Two pillars, 18 in. in length, are attached by supporting blocks to the slotted platform, the tops of the pillars being joined by a cross-bar which is drilled to accommodate adjustable spring-balance bars, as shown in Fig. 7. A pulley at the end of each balance bar carries a tension cord to a spring balance from tension adjusters and pulley blocks attached to the main vertical pillars. Synchros or servomotors can be mounted in hangers or in V-blocks below the gallows. A pulley is fitted to the motor shaft, and a separate length of cord, passing around the motor pulley, joins the hooks of the spring balances. Two balances are provided, to enable torque

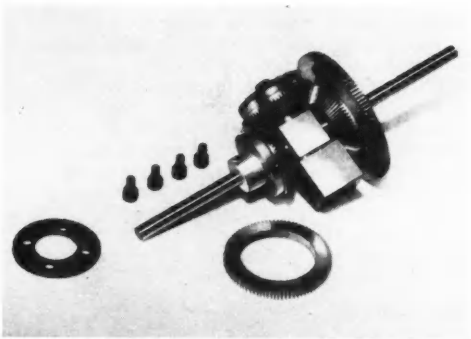

Fig. 6. A differential with two end gears fitted to the bevel gears.

measurements to be made when the direction of motor rotation is reversed, without rearrangement of the gallows. By means of a mark on the pulley and a stroboscope, values of speed can be obtained and the torque/speed characteristics determined. Requiring a surface area of only $1\frac{1}{2}$ sq in. each, the pillar supporting blocks are easily attached to the platform, and the gallows can be readily erected over the prototype assembly at any time to provide a known torque or for measurement purposes. The inclusion of V-blocks as mechanical components is to cater for testing a batch of new motors, and avoiding the fitting of clamps and attaching each motor to a hanger in turn. Finger

Fig. 7. A torque gallows erected over a model in course of construction.

tightening of the V-block clamping screws is sufficient to ensure that the motor will not slip.

Only one manufacturer has so far marketed a torque gallows, but a number of torque "clocks" are available, consisting basically of a shaft turned against a calibrated spring. The instrument is fitted with a chuck by which it is attached to the shaft on which measurement is required and is held in the hand, so as to exert a torque against shaft rotation. The intermediate spring is coiled or uncoiled until the forces balance, and the value of the torque is read from a scale in the handle of the instrument. The application of this instrument is largely limited, and the simple gallows, costing considerably less, is of much wider application in servo work.

Shaft Couplings

Many different varieties of shaft couplings have been produced of both flexible and rigid types. For backlash-free systems, the metal bellows coupling, which is generally considered the only satisfactory solution, permits a slight lateral displacement of the coupled shafts of the order of 0·010 in. and operates at speeds up to 10,000 rpm under conditions of about 240 oz-in. maximum torque.

Naturally, the above values apply only to one small group of products of a particular manufacturer, but are representative of typical values to be expected in components suitable for the shaft sizes under consideration. The lateral displacement permissible for misaligned shafts should be approximately 0·001 in./rev. per convolution. Little published data on the performance of bellows couplings are available, but the graph shown in Fig. 8 gives representative values of angular deflection for a given applied torque, the backlash being twice the angular deflection.

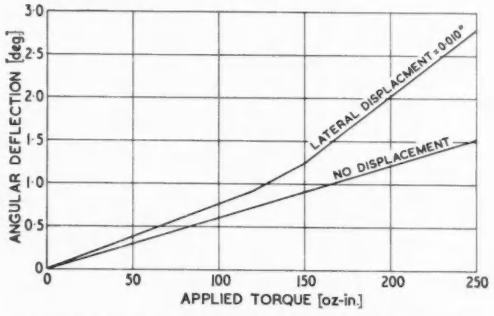

Fig. 8. Static characteristics of a typical bellows coupling, showing the angular deflection for a given applied torque under different conditions of shaft misalignment.

Where backlash is unimportant, or torque is low, inexpensive rubber-bonded couplings are available, in which two metal bushes are bonded together with approximately $\frac{1}{2}$ in. of intervening rubber and provide a simple shaft coupling which is quite satisfactory for most applications.

Rigid couplings are also essential components, in addition to the two forms of flexible couplings already described. Apart from the simple sleeve coupling, a new component of interest has been produced, this being the universal shaft adapter, which, as its name implies, will couple together shafts of different diameters. It consists of a length of $\frac{1}{2}$-in. diameter brass bar drilled along its axis at $\frac{1}{4}$-in. diameter for half its length, and $\frac{3}{16}$-in. diameter for the remainder. Split sleeves reducing to $\frac{3}{16}$- and $\frac{1}{8}$-in. diameter can be inserted at each end respectively to couple any combination of shafts of $\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ in. diameter.

The above four types of couplings have been standardized to fit shafts of $\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ in. diameter. Many other types exist, such as Oldham couplings, multi-jaw couplings, and universal-joint couplings, but standardization of these components appears a little premature at present, since the demand for their use is far outweighed by the demand for the other types.

Miscellaneous Components

For the construction of prototype servomechanisms and any similar device, it is necessary to turn the parts by hand during the experimental stages. Hand cranks have been produced for the different shaft sizes involved, and accurately calibrated dials with split hubs are available for checking rotation of members.

Three different lengths of terminal-strip pillars are available to allow terminal strips to be mounted in tiers. One maker prefers to use machined blocks which provide "steps" on which the terminal strips are screwed. These, however, are expensive and have the disadvantage that two terminals at each end of the strips are obscured by the thickness of metal of the blocks. Pillars are much less expensive and more effective.

Most manufacturers have realized that, to present an extensive catalogue containing many hundreds of items, is not necessarily the best course. To establish the actual parts required to build a prototype design is by no means easy, especially if its designer is unfamiliar with the components. In this respect, it has become a common practice to offer the components in kit form, the contents of a kit being selected for usefulness in a particular application. Thus, there are platform kits which provide, in addition to the platform and its legs, shaft hangers and lengths of shafting, and the designer can then fit whatever pulleys or gears he wishes to the shafts. Gear kits provide sets of gears with shafting and hub clamps only. Torque gallows kits, differential kits with sets of interchangeable end gears, and breadboard kits are also available. These breadboard kits are of special interest, because they contain the widest variety of standardized components and invariably incorporate the contents of the other kits. A typical breadboard kit is shown in Fig. 9.

One manufacturer produces coupling kits, each containing a wide variety of shaft couplings, and kits to build speed reducers of International Frame Sizes in various preselected ratios are rapidly becoming popular. These speed-reducer kits are of great value because a precision speed reducer is an expensive item and to stock only one of each standard ratio can cost hundreds of pounds. In the kits, various gear and pinion assemblies are supplied to be inserted between the bearing plates, as required, and different combinations of these assemblies will provide a limited choice of reduction ratios up to approximately 3000 : 1.

Unfortunately, the ratios generally available are not exact whole numbers, and there remains considerable room for development in this direction to standardize these ratios. Multiples of 60 are recommended, since time is the physical quantity most associated with speeds and velocities. Another useful range of ratios which could be established as a standard is based on $4^n : 1$ where n is a positive integer. In this case, the interchangeable gear and pinion assemblies can all be similar, thus cutting cost, and, if an additional output pinion is

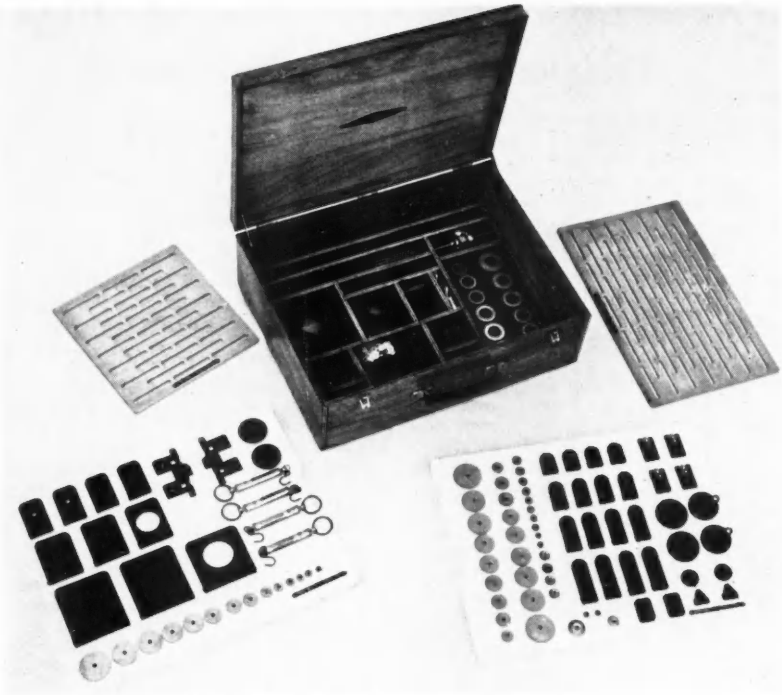

Fig. 9. A typical breadboard servomechanism kit.

provided to produce a 2 : 1 ratio at the last pass, a very wide range of whole-number ratios of 2^n : 1 can be obtained.

Assembly of Standardized Mechanical Components

In the beginning, the design engineer considers the various aspects of the project and produces a rough sketch. Traditionally, the engineer would now call upon the services of the Drawing Office to produce an accurate layout drawing for the prototype but, with standardized mechanical components, this step is eliminated. The engineer can order directly from the maker the parts he needs for his design, with confidence in his ability to construct the prototype himself immediately on receipt of the parts, and to achieve a high degree of accuracy in its construction.

The first stage in the assembly of a model is to attach the rubber feet to one end of the pillars which are to serve as legs for the platform. The legs are then attached to the platform by inserting the screws from above into the platform corners and tightening the screws into the tapped holes in the legs. Electrical components are next fitted to the component hangers, in the case of International Frame Size electrical components by using the clamp screws provided, after which gears, couplings, differentials, etc. are fitted to the shafts of the electrical components. The component hangers are then mounted in their approximate positions on the platform by inserting socket screws from below the platform into the tapped holes in the hangers. The screws are not fully tightened until all the components have been attached.

Working from one side of the platform, shafts are fitted with gears, shaft hangers, dials, etc. in the same way as the component hangers. By using an engineer's square, the component and shaft hangers are aligned, using the machined edges of the platform as a reference. Terminal strips to facilitate electrical wiring are then mounted on the terminal-strip pillars, and these are attached to the platform in the most convenient positions. When the installation has been completed, it can be operated under all the environmental conditions likely to be encountered later and the design can be fully evaluated.

Conclusion

It is considered that the use of standardized mechanical components in development work does much to reduce the overall costs of production models. The advantages gained in development work, both in time and in cost, and the demand for these components are proof of their popularity, and in some cases they are even being used in the production models, as well as for development purposes.

To reduce costs, some compromise must usually be effected. Components of reasonable accuracy produced in quantity can normally give quite satisfactory service at low cost. The compromise should be made by the designer of the equipment, not by reducing the quality of the components, but by asking himself if a specified tolerance is really necessary and by refraining from putting very exacting limits on drawings unless these are vital. The use of standardized mechanical components avoids this tendency.

Force-Transmission Characteristics of Simple and Composite Friction Systems

By K. ROTH

From *Feinwerktechnik*, Germany,
Vol. 64. No. 4, April 1960,
pp. 134-142, 25 illustrations.

WHENEVER friction occurs in mechanisms, whether desirable or not, it is of very great importance to know the magnitude of the coefficient of friction, its variation under changing operating conditions, and the influence of this variation on the maximum transmissible friction forces. While it is not normally possible to control variations in the coefficient of friction under different operating conditions, it is, however, frequently possible to reduce or, if required, to increase the forces caused by friction by suitable design of the friction-transmission arrangement.

It is the object of this paper to investigate the principal types of friction systems and their force-transmission characteristics, in order to establish a basis for the development of various types of friction clutches with substantially constant values of maximum transmissible torque. The analysis given below, however, is sufficiently general to be applicable to all cases in which forces have to be transmitted by friction.

Simple Frictional Systems

Consider two bodies in contact, as shown in Fig. 1. The lower body is moving towards the right, while the

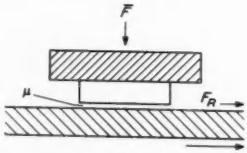

Fig. 1. Linear friction system, as expressed by eq. (1).

upper body is applying on it a vertical force $\overline{F}$. If μ is the coefficient of friction of the mating surfaces, the maximum force that can be transmitted by frictional contact in the plane of the mating surfaces is

$$F_R = \mu \overline{F} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1)$$

In the modified arrangement shown in Fig. 2a, the force F applied by the upper body generates friction and

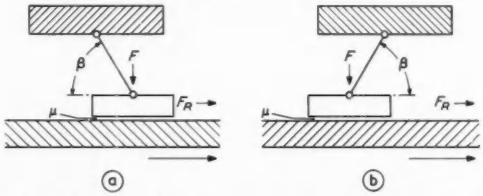

Fig. 2. Non-linear friction systems, as expressed by eqs. (2) and (3).

also has a component in the plane of frictional contact. As a result, the total force transmitted through friction is

$$F_R = \mu F / (1 + \mu \tan \beta) \quad .. \quad .. \quad .. \quad (2)$$

This equation is obtained from the equilibrium conditions, assuming that the lower linkage point is approximately at the level of the plane of contact, so that the additional couple due to F_R can be disregarded. Eq. (2) shows that, when μ is increased, F_R also becomes greater, but to a lesser extent than in the linear relationship expressed by eq. (1).

If the link is rotated about its lower linkage point so that the angle β is greater than 90° (Fig. 2b), the value of tan β becomes negative, with the result that

$$F_R = \mu F / (1 - \mu \tan \beta) \quad .. \quad .. \quad .. \quad (3)$$

In this system, the force transmitted by friction will increase with μ, but to a greater extent than in the linear case.

Force-Transmission Characteristics and their Derivatives

At this point, it is convenient to introduce a "transmission factor" λ, defined as

$$\lambda = F_R / F \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

This factor can be regarded as the equivalent coefficient of friction of a linear system representing the non-linear system considered. In the case of the linear system expressed by eq. (1), $\lambda = \mu$. For the systems expressed by eqs. (2) and (3), the transmission factors are respectively $\lambda = \mu/(1 + \mu \tan \beta)$ and $\lambda = \mu/(1 - \mu \tan \beta)$.

The transmission factor λ takes account of the coefficient of friction μ and the design parameters; hence, it characterizes the frictional behaviour of a system. For example, a system for which $\lambda = 4$ indicates that the transmitted force can be at most four times greater than the force F. This frictional force will occur, of course, only if an external action attempts to move one of the mating surfaces along the plane of contact. The force F_R, therefore, is not produced by the force F, but by a third force which causes an initial movement. In all cases, F is only the "positioning force" producing frictional engagement.

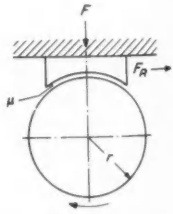

Fig. 3. Linear friction system, as expressed by eq. (1r).

Friction systems with radial arrangements, e.g., a shaft supported on a bearing, or a friction-band and pulley, can also be divided into three main types, according to their design features and λ-characteristics. For such systems, λ denotes the ratio of friction force to force F at the radius r of the shaft or pulley. For the system shown in Fig. 3,

$$F_R / F = \lambda = \mu \quad .. \quad .. \quad .. \quad .. \quad (1r)$$

whereas, for the system in Fig. 4a,

$$\lambda = 1 - e^{-\mu\varphi} \quad .. \quad .. \quad .. \quad (2r)$$

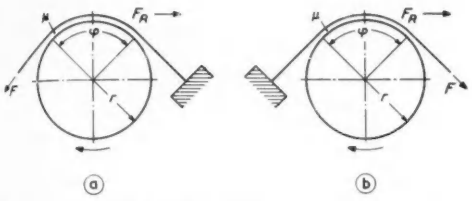

Fig. 4. Non-linear friction systems, as expressed by eqs. (2r) and (3r).

where φ = angle of contact. If the action of this system is reversed by applying the tensioning force F on the right side and fixing the friction-band to a frame on the left side (Fig. 4b), the transmission factor becomes

$$\lambda = e^{\mu\varphi} - 1 \quad .. \quad .. \quad .. \quad (3r)$$

The characteristics of the six simple systems, corresponding to eqs. (1), (2), (3) and (1r), (2r), (3r) are illustrated in Fig. 5, as plots of λ against μ. It can be seen that the friction force F_R can be considerably greater than the force F in systems of type (3). It can even become infinitely great for finite values of μ and β, whereas this is not possible with systems of type (3r) for finite values of μ and φ.

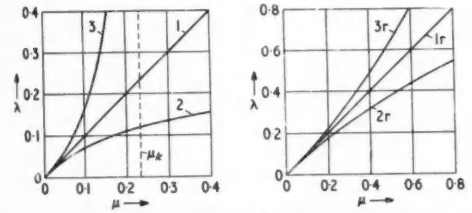

Fig. 5. Characteristics of friction systems, (a) corresponding to eqs. (1), (2), and (3) under the assumption that $\beta = 75°$, and (b) corresponding to eqs. (1r), (2r), and (3r) under the assumption that $\varphi = 1$ radian.

As mentioned before, the coefficient of friction μ is subject to considerable variations due to operating conditions, i.e., static friction, sliding friction, and friction corresponding to boundary-lubrication or hydrodynamic-lubrication conditions. It is also dependent on various other lubrication conditions and on surface changes. Therefore, it is appropriate to consider more closely the influence of changes in the coefficient of friction on the transmission factor λ by examining the derivatives $\lambda' = d\lambda/d\mu$ and $\lambda'' = d^2\lambda/d\mu^2$.

For systems (1), (2), and (3), the derivatives of λ are as follows:—

System (1)	$\lambda' = 1$,	$\lambda'' = 0$	.. ..	(1′)
System (2)	$\lambda' = 1/B^2$	$\lambda'' = -(2\tan\beta)/B^3$		(2′)
System (3)	$\lambda' = 1/C^2$	$\lambda'' = +(2\tan\beta)/C^3$		(3′)

where $B = 1 + \mu\tan\beta$ and $C = 1 - \mu\tan\beta$. Eqs. (2′) show that the relative change in friction force in system (2) is less than the corresponding change in the coefficient of friction. This is an important feature in connection with the design of friction devices which are required to be fairly insensitive to variations in the coefficient of friction. Moreover, it follows from eqs. (2′) that, if large μ-values are used, the force-transmission factor λ will become less sensitive to μ-value fluctuations.

For system (3), eqs. (3′) show that the friction force F_R is extremely sensitive to changes in the coefficient of friction. In arrangements of this type, the friction force can be a large multiple of the force F. For positive μ-values, eq. (3) can be used to obtain a limiting condition

$$\lim_{C \to 0} \lambda = \lim_{C \to 0} (\mu/C) = \infty \quad .. \quad .. \quad .. \quad .. \quad (5)$$

The coefficient of friction required to obtain this "locking condition" will be referred to as the "critical coefficient of friction" μ_k for a specified value of the linkage angle β. If the μ-value varies between the usual limits of zero and unity, the critical condition of eq. (5) will be reached only if $\tan\beta > 1$ or $\beta > 45°$. The transmission factor is then infinite, and the friction force transmitted by the system is limited only by the mechanical strength of the transmission elements.

Considerable similarity exists between this type of "locking engagement" of a friction system and the fully-rigid interlocking of a fixed connection, the only difference being that a fixed connection is independent of friction, whereas a locked friction system remains dependent on friction.

For the radial arrangements of systems (1r), (2r), and (3r), the derivatives of λ are as follows:—

System (1r)	$\lambda' = 1$	$\lambda'' = 0$	.. ..	(1r′)
System (2r)	$\lambda' = \varphi e^{-\mu\varphi}$	$\lambda'' = -\varphi^2 e^{-\mu\varphi}$	..	(2r′)
System (3r)	$\lambda' = \varphi e^{\mu\varphi}$	$\lambda'' = \varphi^2 e^{\mu\varphi}$	..	(3r′)

It can be seen from the negative value of the second derivative and the trend of the values in Fig. 5 that system (2r) is basically similar to system (2). System (1r) is, of course, the rotary equivalent of system (1).

Particular Properties of System (3)

It is possible, by means of the λ-characteristics, to determine the friction-transmission force F_R and to assess the behaviour of a friction system for a wide range of μ-values. As long as $\mu < \mu_k$, F_R will increase to any arbitrary high value more rapidly than μ. The situation is more difficult if $\mu = \mu_k$ or $\mu > \mu_k$, viz.:

$\mu = \mu_k$	$\lambda = \pm\infty$	$\lambda' = +\infty$	$\lambda'' = \pm\infty$
$\mu < \mu_k$	$\lambda < 0$	$\lambda' > 0$	$\lambda'' < 0$

From eq. (4) it is apparent that a negative λ indicates either a negative force F or a negative friction force F_R. The negative force F, however, both as regards magnitude and direction, is precisely the force which would be just

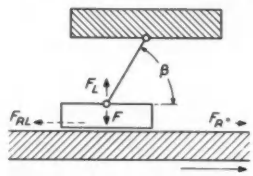

Fig. 6. Release from frictional engagement by a vertical disengaging force F_L, or by a horizontal force F_{RL}.

about, but not quite, sufficient to release the friction members from frictional engagement, if such a force were present. To obtain release, an additional force F_L is necesssry (Fig. 6), which is defined by

$$F_L \geq F - (F_{R'}/\lambda) \quad .. \quad .. \quad .. \quad .. \quad (6)$$

where $F_{R'} < F_R$. Fig. 7 gives, as an example, the $\pm\lambda$-characteristics of a system of type (3), with $\beta = 75°$. Taking, for example, the pair of values $\mu = 0{\cdot}35$ and $\lambda = -1{\cdot}2$ in the region $\mu > \mu_k$ (Fig. 7), substitution in eq. (6) yields

$$F_L \geq F + \tfrac{2}{3} F_{R^*}$$

This indicates that the force required to disengage the mating surfaces must be at least $\frac{2}{3}$ths of the frictional force F_{R^*} plus the force F, which has also to be overcome.

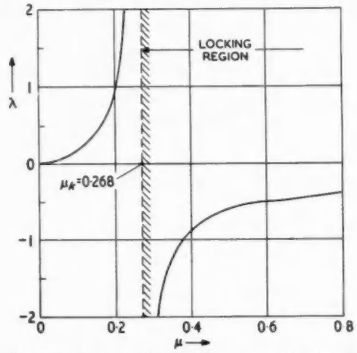

Fig. 7. λ-characteristics of system 3 for β = 75°.

When the coefficient of friction is larger, say 0·6, Fig. 7 gives λ as −0·5. The disengaging force in this case is

$$F_L \geq F + 2F_{R^*}$$

i.e., after overcoming the primary force it must be twice as great as the friction force being transmitted.

For systems which can reach locking conditions, therefore, the primary force F is necessary only to initiate frictional engagement. After engagement has taken place, the force F can be reduced to zero, or can even be negative, without causing disengagement, as long as the transmitted friction force F_{R^*} is greater than zero. Self-sustaining friction systems thus have the property that the disengaging force depends on F_{R^*}.

Instead of a force F_L directed upwards, a force F_{RL}, acting parallel to the plane of contact but in the opposite direction to the friction force F_{R^*}, can be used to bring about disengagement; this horizontal disengaging force can be defined as

$$F_{RL} \geq F_{R^*} - F\lambda \quad .. \quad .. \quad .. \quad .. \quad (7)$$

For example, if $\mu = 0{\cdot}35$ and $\lambda = -1{\cdot}2$, the friction-release force $F_{RL} \geq F_{R^*} + 1{\cdot}2F$. For $\mu = 0{\cdot}6$ and $\lambda = -0{\cdot}5$, $F_{RL} \geq F_{R^*} + 0{\cdot}5\,F$.

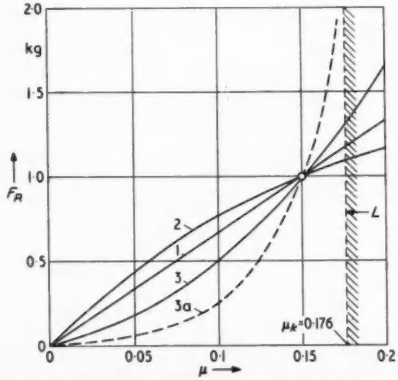

Fig. 8. Friction force F_R as a function of the coefficient of friction μ for systems (1), (2), (3), and (3a), line L indicating the limit of locking conditions for curve (3a).

Thus, for specified values of F_{R^*} and μ, eqs. (6) and (7) provide two possibilities of disengagement, and make it easy to determine which of these requires less force (at the point of application of F or of F_{R^*}) to obtain disengagement.

To sum up, positive λ-values indicate the frictional force that can be transmitted by the system, whereas negative λ-values are an inverse measure of the release force required to disengage a self-sustaining system, with $F = 0$. Fig. 8 shows the friction force F_R plotted against the coefficient of friction μ for the systems (1), (2), and (3), curve (3a) referring to system (3) with $\mu \geq \mu_R$. Since, according to eq. (4), F_R is proportional to λ, these curves are very similar to the λ-characteristics.

Friction System	(1)	(2) β = 75°	(3) β = 75°	(3a)* β = 80°
F [kg]	6·667	10·399	3·001	0·995
ΔF_R [kg]	±0·167	+0·111 −0·114	+0·514 −0·297	+22·133 − 0·573

* Still operative outside the self-sustaining region.

If all the systems transmit a maximum frictional force F_R of 1 kg with, say, $\mu = 0{\cdot}15$, the engaging force F will be different in each case. If, for example, the fluctuation of the coefficient of friction $\Delta\mu = \pm 0{\cdot}025$, the corresponding change ΔF_R will also be different for each system. The above table (based on $F_R = 1$ kg and $\mu = 0{\cdot}15$) gives numerical values indicating that system (3) is suitable for generating large friction forces F_R from small forces F, whereas system (2) gives F_R-values which are less sensitive to variations in the coefficient of friction.

(To be concluded)

Experience with Russian Liquid-Metal Pumps

(Concluded from page 116)

50°C, and the fourth for 1000 hr on sodium at temperatures between 300° and 400°C. All these pumps are easy to operate and are very reliable.

It is true that a.c. conduction pumps can be used satisfactorily only for deliveries up to 10,000 litres/hr, induction pumps with a travelling magnetic field providing a better solution where higher outputs are required. One pump of this type consists of two flat inductors arranged above and below a channel through which the liquid metal flows. The width of the channel, which is made from a chrome-nickel steel, is 150 mm, the height being 6·1 mm in one design and 8·7 mm in another. A three-phase eight-pole winding is laid into grooves in the inductors, together with copper tubes for cooling water. Copper bars inside the channel have the same function as the short-circuiting rings of an asynchronous motor.

One pump of this type, which had a peak efficiency around 15%, was operated with sodium-potassium for 300 hr at a temperature between 150° and 200°C, but it was found that its cooling system failed to provide adequate protection of the winding against heat, and wetting of the winding caused a breakdown of the insulation on two occasions. It is hoped, however, that, after some modifications, this pump will operate satisfactorily at temperatures between 200° and 250°C and with a delivery up to 30,000 litres/hr.

Experience with Russian Liquid-Metal Pumps

By P. L. Kirrilov, V. A. Kuznetsov, N. M. Turchin, and Yu. M. Fedoseyev

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Vol. 7, No. 1, July 1959,
pp. 11–17, 7 illustrations.

Pumps designed for handling water and similar liquids are unsuitable for liquid metals such as sodium and sodium-potassium, because of the difficulty in sealing and operating such pumps at the high temperatures involved (300° to 500°C). Special designs of centrifugal and electromagnetic pumps have therefore been developed for this purpose.

The design of centrifugal pumps for temperatures below 400°C no longer presents any difficulties, and, in fact, designs operating between 550 and 600°C are currently available. The high electrical conductivity of liquid metals has made possible the design of pumps in which the hydrodynamic pressure is produced by electromagnetic methods, rendering the problem of sealing much easier. However, these pumps have a very low efficiency, i.e., only about 50% of that of centrifugal pumps of comparable ratings, though they have been used successfully in experimental and semi-industrial plants, where their advantages outweigh their disadvantages. Nevertheless, it cannot yet be said which of the two types will be adopted for future large-scale plants.

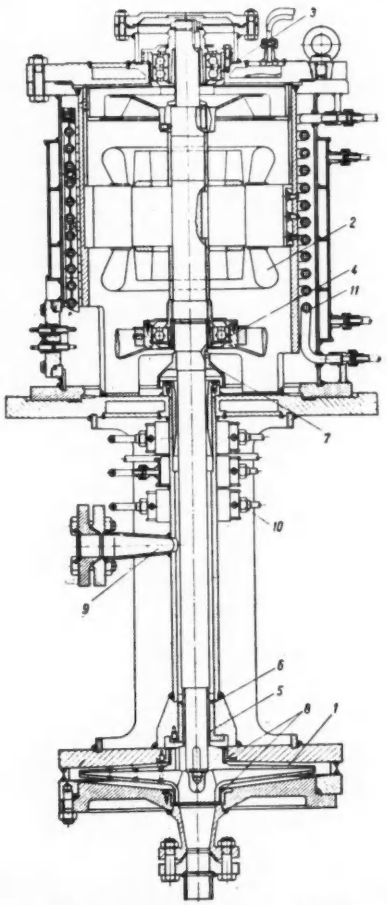

Fig. 1. Centrifugal liquid-metal pump with canned motor. (1) Impeller. (2) Asynchronous motor. (3), (4) Ball bearings. (5) Steel sleeve. (6) Beryllium-bronze bush. (7) Protective collar. (8) Sealing rings. (9) Drain for removing leakage metal. (10), (11) Cooling arrangements.

Fig. 1 shows a centrifugal canned-motor pump which, at 990 rpm and with a head of 23 metres of liquid metal, delivers 10,000 litres/hr. At 1450 rpm, the maximum head is 55 metres. In this pump, the impeller, 415 mm in diameter, has fourteen blades and is driven by a 10-kW asynchronous motor. The impeller is provided with seven holes of 8 mm diameter for relieving axial thrust. The motor and the impeller are mounted on a common shaft, supported in three bearings. A collar prevents the lubricant from the upper ball bearings from seeping into the liquid metal. The lower bearing, whose sleeve is made of a high-alloy steel and the bush of a beryllium bronze containing 2% beryllium, is lubricated by the liquid metal, the clearance between the sleeve and the bush being, when cold, 0·20 to 0·25 mm. The sealing rings are made of the same beryllium bronze as the bearing bush, while all other parts of the pump are made of a chrome-nickel steel. The motor is cooled internally by an inert gas, an additional water-cooled coil originally provided proving unnecessary.

In tests with water, this pump showed an efficiency of 40% at 990 rpm and with a delivery of 6500 litres/hr. The pump was then run for 2000 hr with sodium-potassium at temperatures ranging from 200° to 400°C but, after 1500 hr, the bearing bush showed a wear of 2 mm on one side and had to be replaced. The main disadvantages of this design are considered to be difficulties in dismantling and its heavy weight.

Another Russian pump of the same type is more compact and of simpler design. This pump is driven by a 2900-rpm canned motor, the rotor of which is cooled by an inert gas, the casing and bed-plate being water-cooled. The impeller, 164 mm in diameter, is mounted on a shaft supported in two bearings. The lower bearing is lubricated by leaking metal, which is then allowed to flow into the sump, the amount of this leakage varying from 50 to 200 litres/hr, according to the load.

At temperatures near 450°C the service life of this bearing showed a rapid decrease, because of the decreasing strength of the beryllium bronze. Better results were obtained with a bearing which had a high-alloy-steel sleeve and a beryllium-bronze bush, the clearance between these two components being from 0·12 to 0·15 mm. Smaller clearances cause seizure, while greater clearances result in a reduced service life. This pump was run for 2000 hr with sodium-potassium, and for 7000 hr with sodium, with an average metal temperature of about 200°C. During the operation of these pumps the penetration of sodium vapours into the motor, and their condensation on the internal walls of the machine, led to the formation of sodium hydroxide, resulting in a rapid destruction of the winding.

At higher temperatures, bearings become the weakest

point in the machine. In order to avoid this drawback, a number of designs have been developed which incorporate a frozen-sodium seal, this seal also acting, in effect, as an additional bearing. A pump of such a design is illustrated in Fig. 2. This pump, which has an output of 25,000 litres/hr at a head of 100 metres, is driven by a 14-kW motor operating at 2960 rpm. The shaft (3) is supported in two radial ball bearings (5) at the lower end and in two double-purpose ball bearings (4) at the upper end, the frozen-sodium seal (6) acting as a third bearing. In the region of this seal, the pump shaft is surrounded by two cooling chambers, so that the cooling medium and the frozen sodium are separated by two metal partitions, enabling water to be used as the coolant. The frozen-sodium seal (Fig. 3) is not only efficient, but also has the advantage of being entirely free from wear and of being able to resist practically any temperature.

The main shortcoming of this type of pump is leakage

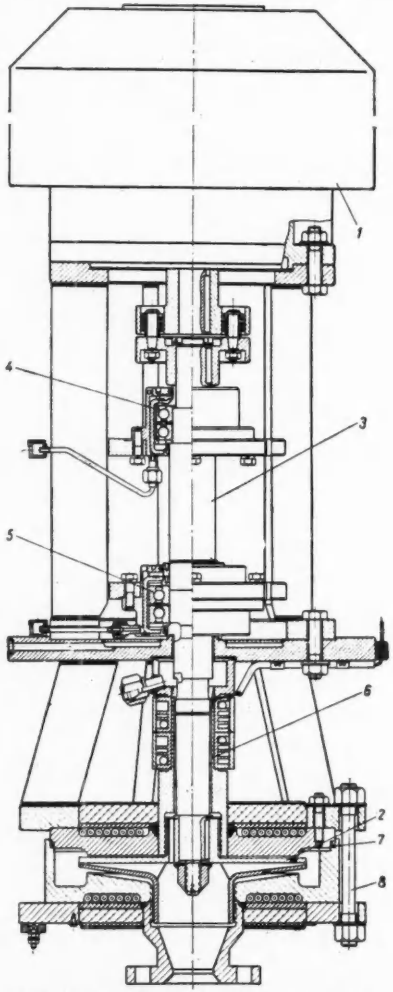

Fig. 2. Centrifugal liquid-metal pump with frozen-sodium seal. (1) Motor. (2) Impeller. (3) Shaft. (4) Double-purpose ball bearings. (5) Radial ball bearings. (6) Frozen-sodium seal. (7) Packing. (8) Bolt.

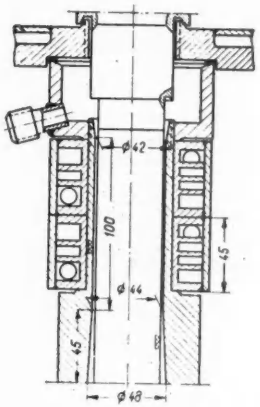

Fig. 3. Arrangement of one design of frozen-sodium sea

through the casing joint as a result of sudden changes in temperature, which cause unequal expansion of components during heating. However, this difficulty can be avoided by heating the machine prior to starting, in which case the total amount of sodium leakage is from only 1 to 2 grams per day.

Two pumps equipped with frozen-sodium seals of this type have been tested for about 2000 hr at temperatures between 400° and 500°C and are still in operation. A third pump of similar type is cooled with sodium-potassium by means of a special electromagnetic pump and a heat exchanger. This pump has been in operation for more than 5000 hr at average temperatures of 400° to 500°C. Experience seems to indicate that pumps with frozen-sodium seals are one of the simplest and most reliable methods of handling sodium.

Of the many types of electromagnetic pumps in existence, a.c. conduction pumps are considered to be particularly suitable for use in experimental plant. This is mainly due to the fact that these pumps do not require special current-supply equipment and can readily handle liquid metal at temperatures between 400° and 600°C, as distinct from induction pumps, which are unsuitable for this purpose. A typical single-phase a.c. conduction pump, rated at 220 V, 30 A, has an output of 4000 litres/hr at a pressure of 2 kg/cm². The pump and supply transformer have a common magnetic circuit made of electrical steel, rectangular wire, with a cross-sectional area of 4·55 mm², being used for the two coils of the primary winding, each of which has 130 turns. The winding of the pump and the secondary winding of the transformer are constructed as a single unit from water-cooled 20 × 5 mm copper tubing. Current is fed from the secondary winding of the working section, which consists of flattened thin-walled chrome-nickel tubes with a wall thickness of 0·5 mm, located close to each other and connected in series. With this design, it has been found possible nearly to double the head and to compensate for armature reaction.

Four of these pumps have been in operation at various plants. One pump operated for 250 hr on liquid sodium at a temperature of 450°C, and another for over 2500 hr on sodium-potassium at a temperature of about 250°C, while the third pump operated for over 3500 hr on sodium-potassium at a temperature of 40° to

(Concluded on page 114)

Programme Costs for a Manned Space Station

By R. H. LUNDBERG and T. E. DOLAN*

THE advent of space exploration, while opening up new frontiers, has also posed a number of problems, one of which is in connection with the cost of space programmes. Specifically, each programme represents such a large investment that it is necessary to present a complete costing picture for the entire programme, and it is therefore the object of this paper to develop the costs for a manned space station and to examine and discuss their composition.

In order to establish a programme, it is assumed that the objective is to develop a versatile manned space station which fulfils a number of basic requirements, including the following:—

(1) The station must be capable of conducting scientific and engineering tests, both manned and unmanned.
(2) The station must have sufficient flexibility to permit changing the testing programme with little or no modification.
(3) The station must support all facets of space-crew training, including injection into orbit, rendezvous, navigation, in-space repair and maintenance, entry, and point-return manœuvring.
(4) The costs of the test-station system must be reasonable, and fiscal-year funding requirements must be compatible with national budget policies.

The primary features of a system which meets these requirements include a modular concept of a separate entry vehicle and space station. Upper and lower fan-shaped lightweight structures on the sun-orientated vehicle support solar cells which, in this particular example, provide 5·5 kW of electrical power for the space test-station assembly. A 300-mile earth orbit has been selected to provide a true space environment, but is still close enough to afford economical proximity to the earth and also to avoid the radiation hazards of the inner Van Allen belt. The size of the station has been selected as suitable for accommodating a crew of three for fourteen days, crew return being accomplished by their entering the entry vehicle (which is a lifting manœuvrable body), separating from the space station, and making a point return to a preselected landing site. Subsequent manned use of the station consists of injecting an entry vehicle into orbit and effecting a rendezvous with it. Included in subsequent missions is an entry-vehicle payload of 583 lb of expendable materials, such as food and oxygen, for reprovisioning the test station. It is also possible, by the modular design approach, to make the station of any desired size for any reasonable man/day requirements and to avoid reprovisioning payload weights on subsequent operations. The test station under consideration has a total weight of 10,090 lb, the entry vehicle weighing 5750 lb and the space laboratory (including 773 lb of test and associated equipment) 4340 lb.

This space-station system permits development and qualification and scientific testing under both manned and unmanned conditions, includes the necessary elements for all phases of crew training, and has the required flexibility of contents and arrangement. As such, it is concluded that the assembly fulfils the conditions stipulated in the programme.

The basic objectives in establishing the development programme to provide this manned space station are to produce the best-possible programme consistent with the overall national effort which will successfully accomplish the basic objectives most economically in the shortest practical time. The programme falls naturally into three distinct phases, i.e., (1) developing the entry vehicle,

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TABLE I: SUMMARY OF PROGRAMME COSTS FOR THE MANNED SPACE STATION

	COSTS [millions of dollars]								
	ENTRY VEHICLE			SPACE LABORATORY			MANNED SPACE STATION		
	NR	*R*	Total	*NR*	*R*	Total	*NR*	*R*	Total
AIRBORNE SYSTEMS									
Entry Vehicle									
Structure	42·0	19·5	61·5	—	—	—	—	6·0	6·0
Equipment	47·2	20·8	68·0	—	—	—	—	6·4	6·4
Space Laboratory									
Structure	—	—	—	37·4	4·0	41·4	—	3·2	3·2
Equipment	—	—	—	65·5	41·0	106·5	—	32·8	32·8
Boosters	52·4	47·2	99·6	6·9	9·6	16·5	103·1	49·2	152·3
TOTALS	141·6	87·5	229·1	109·8	54·6	164·4	103·1	97·6	200·7
FLIGHT-TEST PROGRAMME									
Ground-Support Complex	99·5	—	99·5	36·7	—	36·7	59·6	—	59·6
Flight-Test Operations	38·7	—	38·7	7·2	—	7·2	16·6	—	16·6
Support Programmes	15·0	—	15·0	7·7	—	7·7	9·7	—	9·7
TOTALS	153·2	—	153·2	51·6	—	51·6	85·9	—	85·9
SYSTEMS MANAGEMENT	6·9	—	6·9	3·9	—	3·9	5·1	—	5·1
OVERALL TOTALS	301·7	87·5	389·2	165·3	54·6	219·9	194·1	97·6	291·7

(2) developing the space laboratory, which has been given the copyright name of "Satellab", and (3) developing the manned space station; for the purposes of this paper, it is assumed that a single mission will accomplish the immediate objectives.

In general, each of the three phases of the programme will require the following:—

(1) A flight-test programme to qualify the vehicle and its various combinations of systems.
(2) The necessary technicians, facilities, and equipment to support the individual flight-test programme.
(3) The necessary hardware to conduct the flight tests, including vehicles and boosters.
(4) A research and development programme to produce the technology to develop the hardware and to qualify the various components and systems in the hardware items.
(5) Supporting activities, such as documentation, training, flight simulators, and spares.

Parametric cost data have been developed for costing purposes based on past experience, related programmes which have been conducted or costed, and vendor/subcontractor quotations. For optimum programme cost, a flight-test programme must be developed which ensures that only essential tests will be planned, that there will be a maximum safe number of tests per launching, and that there will be a minimum number of vehicles, with only those particular systems required to conduct specific tests, and a minimum number of boosters, which will be of standard available types of a size adequate for specific tests.

The research-and-development part of the programme phases are basically engineering activities covering study and analysis, developmental tests to provide engineering information, and qualification tests, such as functional and reliability tests, to prove component and system design. These activities are supported by costly purchased or fabricated items such as components, systems and sub-systems, and structural assemblies.

Programme Costs

A breakdown of the total costs of the programme is given in Table I, which summarizes the costs in terms of the airborne systems, the flight-test programme, and systems management, the individual costs being further broken down in terms of non-recurring costs (*NR*) or recurring costs (*R*).

It will be seen from Table I that the total programme cost of the manned space test-station is $900,800,000, of which the overall costs of the entry vehicle is $389,200,000, of the space laboratory $219,900,000, and of the manned space station, comprising assembly of the entry vehicle and "Satellab", $291,700,000. The total non-recurring costs are $661,100,000, representing 73·4% of the total programme costs, as against 26·6% for the recurring cost.

These total costs are also summarized in Fig. 1, which, in addition, shows the cumulative costs of the programme over a period of five years to completion. It will be seen that the maximum fiscal-year funding requirement on this five-year schedule is $284,700,000 between the first and second years after the start of the project.

Other analyses of the cost of the programme have also been made, including costs of research and development, design, tooling, and testing, and hardware and booster requirements, including mission requirements. Some of

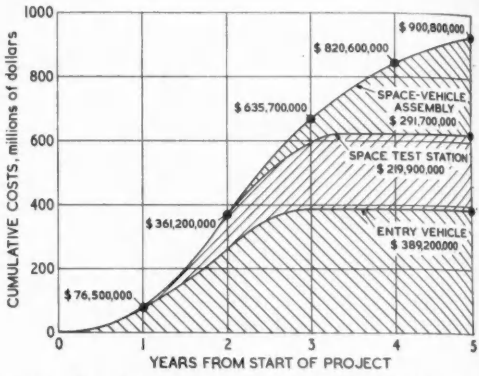

Fig. 1. Cumulative costs of the manned space-station programme on the basis of a five-year schedule.

the conclusions derived from these breakdowns of costs are as follows:—

(1) The actual assembly, i.e., the entry vehicle and "Satellab", orbiting the earth costs $12,100,000, representing only 1·3% of the total costs (entry vehicle = 0·3%, "Satellab" = 1·0%).
(2) If, after completion of the programme and mission outlined, it is considered desirable to send up a second complete assembly three months later, the total costs of this follow-on programme would be $27,000,000, or 3% of the cost of the initial programme.
(3) The total equipment costs for the systems, etc. in the space vehicle are 23·7% of the total programme costs. On a *pro-rata* unit cost, this represents $3050 per pound. After development, equipment costs for subsequent missions are reduced to $1500 per pound. The corresponding costs for structures are $2770 and $755 per pound respectively.
(4) The engineering-design costs ($91,600,000) represent 10·2% of the programme costs, while the total engineering effort for the programme ($255,600,000) represents 28·4% of the programme costs.
(5) Qualification-testing costs ($86,800,000) represent 9·6% of the total programme costs, while all testing ($237,700,000), including qualification costs, represents 26·4% of the total costs.
(6) Total research and development costs ($49,300,000) represent 5·5% of the total programme costs, while crew-training costs ($30,000,000) represent 3·3% of the total costs.
(7) Range-modification costs are $55,500,000, or 6·1% of the total costs. Tooling costs are $39,200,000 or only 4·3% of the total, while spares and support costs ($32,300,000 each) each represent 3·6% of the programme costs.

Analysis of Cost Breakdowns

The total programme costs and fiscal-year funding rates seem to be reasonable. Inasmuch as the present U.S. economy is currently supporting space programmes at approximate $1,000,000,000, with a yearly funding rate of from about $200,000,000 to $300,000,000, it would appear to be possible to conduct the programme in proper phase with these other programmes and still maintain current U.S. national-budget philosophy.

Because the total hardware and system-testing requirements are more than 25% of the total programme costs, the cost pattern suggests the desirability of employing maximum utilization of components, systems, and even vehicle assemblies plus their associated boosters, previously developed for other space missions. In this instance, a versatile modular concept for the end vehicle appears most attractive. Similarly, the proportion of research and development costs (5·5%) indicates that a special effort should be made towards the development of items that are versatile enough to be used in alternative programmes and missions. Thus, technical "dead-end" concepts and limited-growth capabilities must be avoided.

The need for the modular space-vehicle concept is further highlighted by the tremendous difference (in the ratio of 3 : 1) between non-recurring and recurring costs, as indicated in Table I, and this difference is considered to be one of the most important aspects of these cost studies. In other words, if it is possible to develop in a given programme such as that outlined in this paper a vehicle which is versatile, i.e., one with manœuvring characteristics, efficient lunar growth capabilities, etc., such a vehicle can be used in additional space programmes, and a non-recurring cost of literally hundreds of millions of dollars can be avoided in subsequent programmes. This immense saving is, therefore, a major practical reason for fostering the concept of modular construction of space-vehicle systems.

The flight-test programme cost of $290,700,000, including the training programme cost of $30,000,000, represents a significant proportion (32·2%) of the overall programme costs. One manned entry flight will cost $8,300,000, while one manned space-station flight will cost $27,000,000. One conclusion which seems evident from these data is that rather advanced simulator facilities for training space crews can be justified, if flight-training requirements are thereby reduced or the chances of mission success are improved by reducing the possibility of human error.

Because of the importance of cost and funding studies on total programme feasibility, it appears that procurement agencies will increase their emphasis on adequate treatment of this subject in the conceptual phases. This could even take the form of contracting for such services from a company with these specialized talents, independent of the parties conducting technical-feasibility studies. It is apparent that many of the best sources for costing information lie within the area of jurisdiction of procurement agencies, and access to this information is quite limited to-day. It is recognized that many problems exist relative to the dissemination of this information, even on a careful highly selective basis. However, the quality of the end product—the cost study—will be in direct proportion to the amount of information supplied to the contractor. Consequently, the need for a more flexible cost-dissemination policy on the part of procurement agencies is indicated.

Fundamental parametric cost data to support the pricing of space programmes in the conceptual phase are at present almost non-existent. However, this is not necessarily a matter of concern but, rather, is indicative of the fundamental position in exploring this new dimension. Nevertheless, it does highlight the need for the dissemination of cost information between industrial organizations and between industry and governmental agencies. This, in turn, suggests that greater emphasis should be placed on this subject in symposia, in conferences, and in the formulation of the policies of procurement agencies.

A Review of High-Energy Forming Methods

By W. W. Wood*

High-energy forming has been receiving considerable publicity during the past few years because it is generally associated with the forming of high-strength, high-temperature materials such as the super-alloys and the refractory metals. However, the designation "high-energy forming" is a loose one, as it takes only a required amount of energy to form a given part, irrespective of how the energy is applied, and more realistic names can be applied to each of the basic so-called high-energy forming methods.

Thus, explosive forming could more aptly be called high-energy-rate or high-kinetic-energy forming, because the energy is introduced so rapidly into the part, while drop-hammer, trapped-rubber, and floating-piston methods could also be termed high-kinetic-energy forming, owing to the velocities and relatively large masses involved. Similarly, hot-fluid and integrally heated die methods could simply be termed high-temperature forming, because heat is the principle source of energy in these methods.

The object of this paper is to clarify the different high-energy forming methods and to describe the basic mechanism of each. It is true that there is an abundance of literature on these forming methods, but much of it is confusing and even contradictory with regard to what can be accomplished in the forming of certain materials. For this reason, an attempt has been made to show the limitations and applications of each high-energy method, based on fundamental concepts in the plastic deformation of metals.

It should be noted throughout this paper that most of the comparisons and limitations given are based on qualitative, rather than quantitative, figures, owing to the lack of proven and correlated quantitative data. This fact indicates the need for a more progressive programme to establish these quantitative data, so that a more factual report can be made.

Classification of Different Forming Methods

In the production of current high-energy forming methods, the parameters used are mass, velocity, tem-

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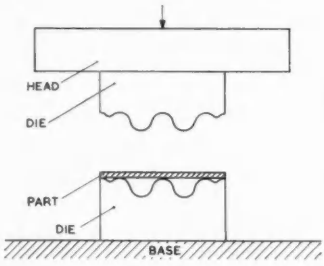
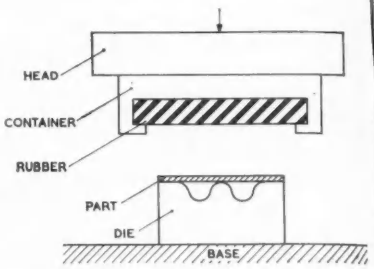


Fig. 1 (left). Schematic arrangement of the drop-hammer method of forming.

Fig. 2 (right). Schematic arrangement of the trapped-rubber method of forming.



perature, and ultrasonic sound waves. For this reason, high-kinetic-energy forming methods have here been divided into large-mass methods, high-velocity methods, high-temperature methods, and induced sound-wave methods.

Large-Mass Methods

Of the various large-mass methods of forming used, two of the older and more conventional methods are drop-hammer forming (Fig. 1) and trapped-rubber forming (Fig. 2), in both of which the principle of large mass, at the expense of velocity, is utilized. Thus, for example, with these methods, if the weight W of the head and die is assumed to be 10,000 lb, and the impact velocity v is 20 fps, then the kinetic energy K.E. is approximately

$$\text{K.E.} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(W/g)v^2 = \tfrac{1}{2}(10{,}000/32{\cdot}2)(20)^2 = \tfrac{1}{2}(310)\,(400) = 62{,}000 \text{ ft-lb.}$$

From the above, it can be seen that, although a fairly sizeable energy is developed in both methods, the mass contribution is roughly the same as the velocity contribution.

Another high-kinetic energy method is the floating-piston method (Fig. 3), which makes more use of the velocity factor. Thus, for example, if the weight W of the moving mass is assumed to be 325 lb and the impact velocity v is 100 fps, the kinetic energy K.E. is approximately

$$\text{K.E.} = \tfrac{1}{2}(10)\,(10{,}000) = 50{,}000 \text{ ft-lb.}$$

It can be seen that, with an assumed velocity 5 times greater and a mass 30 times smaller than in the case of drop-hammer forming, the total energy developed by the floating-piston method is roughly of the same order of magnitude as that of the lower-velocity large-mass methods. However, the velocity factor in the floating-piston method contributes about 1000 times as much as the mass in the total kinetic energy.

High-Velocity Methods

High-velocity methods comprise explosive-gas forming, explosive-liquid forming, and electrical-discharge forming. In explosive-gas forming, the firing of an explosive charge in air above the part creates a high-velocity air blast which drives the part into the die. In explosive-liquid forming, the explosive charge is immersed in a liquid, e.g., water, as shown in Fig. 4. Electrical-discharge forming is similar to explosive-liquid forming, except that the explosive charge is replaced by a pair of electrodes to produce an electrical discharge.

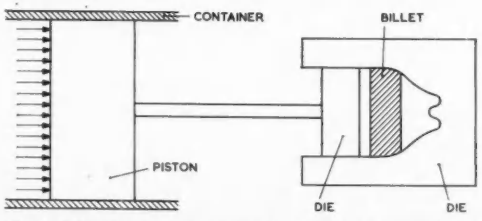


Fig. 3. Schematic arrangement of the floating-piston method of forming.

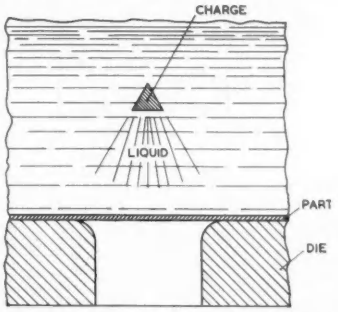


Fig. 4. Principle of the explosive-liquid method of forming.

In all these high-velocity methods of forming, the contribution of mass to total kinetic energy is virtually negligible, compared with the contribution made by velocity. For instance, in the case of explosive-gas forming, if the weight of the moving gas is assumed to be 0·3 lb and the impact velocity 3000 fps, the kinetic energy K.E. is approximately

$$\text{K.E.} = \tfrac{1}{2}(0{\cdot}01)\,(9{,}000{,}000) = 45{,}000 \text{ ft-lb.}$$

Similarly, in the case of explosive-liquid and electrical-discharge forming methods, if the weight of the moving liquid front is assumed to be 6 lb and the impact velocity 700 fps, the kinetic energy K.E. is approximately

$$\text{K.E.} = \tfrac{1}{2}(0{\cdot}2)\,(500{,}000) = 50{,}000 \text{ ft-lb.}$$

Thus, the contribution of velocity is of the order of 900,000,000 times as high as that of mass in explosive-gas forming, and 2,500,000 times as high in explosive-liquid or electrical-discharge forming. It should, however, be noted that the kinetic energy available in explosive-forming methods is only a small portion of the total energy generated by the explosion. In fact, most explosive-forming operations have an efficiency of only 15 to 20%.

High-Temperature Methods

The two basic high-temperature methods of high-energy forming are those using integrally heated dies and those using hot fluids. In the method using integrally heated dies (Fig. 5a), heat is supplied to the two solid-metal die halves by cartridge-type or other suitable

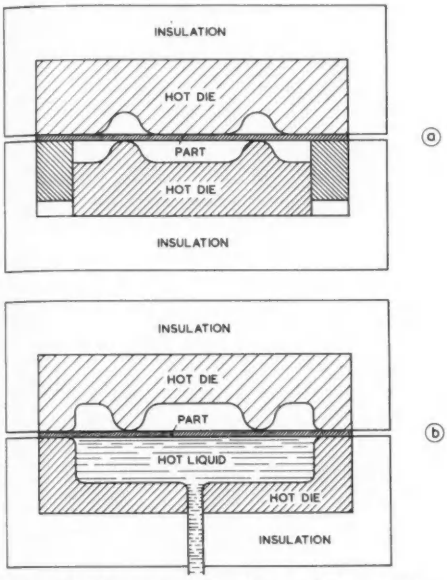


Fig. 5. High-temperature forming methods, showing (a) forming with integrally heated dies, and (b) hot-fluid forming.

heaters, the dies being completely surrounded by insulation. Various forms of this system are currently in use, such as heated-platen machines.

In the hot-fluid forming method (Fig. 5b), both heat and pressure are supplied by a hot liquid-metal alloy, providing considerable advantages over the solid-metal method, as will be shown later.

In order to understand the energy involved in these high-temperature methods of forming, it should be noted that, for example, stainless steel, with a flow stress of 100,000 psi at room temperature, has a flow stress of only about 5000 psi at 1200° F. As a result, it can be shown that, if it requires 15,000 ft-lb of energy to form a particular stainless-steel panel, the contribution provided by the heat obtained from the solid die or fluid amounts to about 14,250 ft-lb. Indeed, heat supplies approximately 90 to 95% of the energy required in forming with high-temperature methods, provided, of course, that metallurgical considerations do not prohibit forming at the temperatures necessary to reduce the flow stress to the required level.

Induced Sound-Wave Methods

The induced sound-wave method of high-energy forming (Fig. 6) is a variant of high-temperature forming methods in that a second type of energy is superimposed on the mechanical forming energy.

As an example of the energy produced by this method,

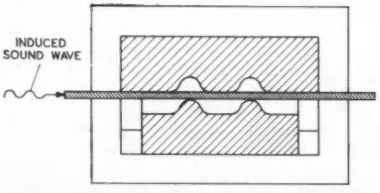


Fig. 6. Principle of the induced sound-wave method of forming.

if it is assumed that the velocity of the ultrasonic wave in steel is $17{\cdot}5 \times 10^6$ fps, and the weight of the moving wave front is as little as 10^{-8} lb, the kinetic energy K.E. is approximately

$$\text{K.E.} = \tfrac{1}{2}(3 \times 10^{-10})(3{\cdot}2 \times 10^{14}) = 50{,}000 \text{ ft-lb}.$$

It can therefore be seen that, even with a very small mass, considerable energy can be induced into a part being formed. How this energy is utilized in forming will be discussed in the next section.

Theory of Plastic Deformation of Metals

In considering the theory of plastic deformation of metals, the effects of time dependence, temperature dependence, and hydrostatic pressure, and the mechanism of plastic flow in the high-energy forming methods previously described must be taken into account, and these factors are discussed separately.

Time Dependence

The theory of the effects of speed on the plastic deformation of metals has not been treated very thoroughly in the literature. In discussing this subject, it would seem most appropriate to start with the simple impact test, such as the Charpy impact test, in which, although the speed of deformation is slow (18 fps), compared with some of the explosive methods of forming, it is still comparable with the speed of the slower methods, such as drop-hammer and trapped-rubber forming. Considerable data can be obtained from this type of testing and, by proper extrapolation, the theory can be applied in a qualitative manner to high-velocity systems. It should be remembered that there are considerable limitations in applying impact data to high-speed forming, because the simple Charpy results are based on variables other than metallurgical factors, such as size effect and the shape of notches causing brittle failure.

In studying the impact values of materials, it is found that there are two distinct types of metal behaviour apparent when impact energy E is plotted as a function of temperature T, as shown in Fig. 7, in which E as a function of T is plotted for a low-carbon steel (Fig. 7a) and for aluminium (Fig. 7b). The energy to fracture is an indication of the notch sensitivity of materials, and it can be seen that a material such as a low-carbon steel exhibits ductile behaviour at elevated temperatures and brittle behaviour at low temperatures when deformed as in the Charpy impact test, with a transition region between, in which there is a considerable increase in ductility over a small range of temperature increase. In the case of ductile notch-insensitive aluminium (Fig. 7b), there is only a very slight increase in impact energy with temperature at the beginning, followed by a slight decrease in impact ductility after a certain temperature has been reached.

The transition region in Fig. 7a is completely dependent on the material concerned, some materials exhibiting well-defined transition regions from brittle to ductile impact behaviour, while others have a more uniform behaviour. In this connection, it may be said that, insofar as the impact properties of materials are concerned, the application of heat is unnecessary in the case of semi-austenitic stainless steels, helpful in the case of martensitic stainless steels, tool steels, and the superalloys, and essential in the case of beryllium and the refractory metals.

It has been shown that an increase in strain rates in

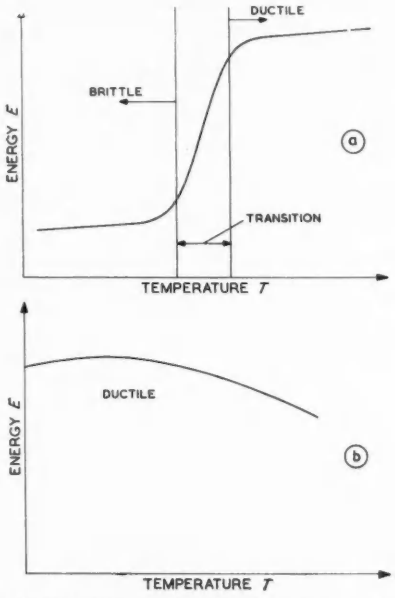


Fig. 7. Impact energy as a function of temperature for (a) a low-carbon steel, and (b) aluminium.

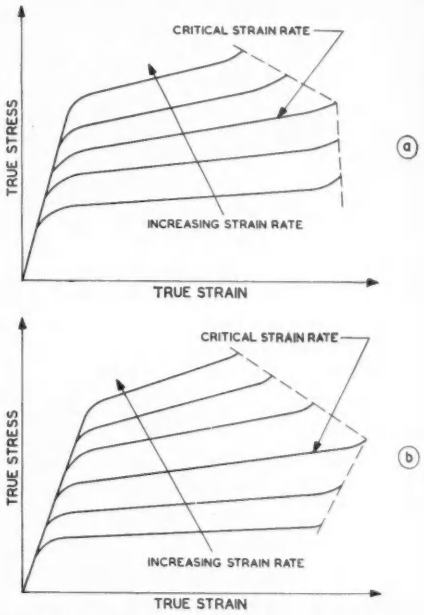


Fig. 8. True stress as a function of true strain, showing the two basic types of curves.

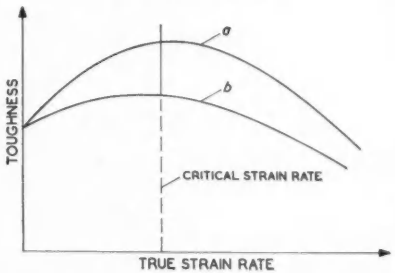


Fig. 9. Toughness as a function of true strain rate (a) for the curves shown in Fig. 8a, and (b) for the curves shown in Fig. 8b.

tension tests has the inverse effect of that obtained by increasing temperature, as indicated by the following equation[1] for velocity-modified temperature T_M:—

$$T_M = T(1 - k \log_e (\varepsilon'/\varepsilon'_0)$$

where T is the test temperature [°K], ε' is the true strain rate ($= d\varepsilon/dt$), and k and ε'_0 are constants.

This equation shows that, as the true strain rate ε' increases, the velocity-modified temperature T_M must decrease to maintain the relationship, and suggests that increasing strain rates beyond 18 fps for Charpy tests will greatly lower the impact energy to fracture. This can be shown more clearly by studying the effect of strain rate on true stress/strain curves, of which there are two basic types for various materials, as shown in Figs. 8a and 8b.

In both cases, true stress increases with strain rate ε'; however, the total true strain to fracture holds fairly constant and then diminishes in the case of the curves in Fig. 8a, whereas it first increases slightly and then diminishes in the curves in Fig. 8b. In general, the flow stress is increased considerably with increasing strain rates, whereas true strain to fracture increases very slightly, if at all, and then usually diminishes.

At this point, it is desirable to discuss toughness, which is a common mechanical property of materials relating more to high-energy forming. Toughness can be considered as the area under the true stress/strain curves shown in Figs. 8a and 8b, and is a measure of the energy-absorption ability of a metal. Fig. 9 shows toughness as a function of true strain rate ε' for the curves in Figs. 8a and 8b, and demonstrates that, although the true strain to fracture does not increase with increasing strain rates, the toughness of metals increases to some critical strain rate and then diminishes. This toughness is the ability of the metal to deform plastically under shock-loading without fracture.

It can therefore be realized that all high-velocity forming methods have decided limitations with regard to the materials that can be formed. High toughness is essential, and the strain rate must be selected in such a way as to confer maximum toughness on the material.

Temperature Dependence

It has already been shown that an increase in temperature lowers the flow stress of a material and hence the energy required for forming. However, a more important benefit than reduced flow stress is derived from increased temperature, i.e., a greatly increased true strain to fracture, and this increase in strain can be extremely large for some materials. For example, tungsten increases in conventional strain from less than 1% at room temperature to as much as 55% at 1950° F.

This greatly increased strain considerably improves formability, though it is true that the total amount of true strain to fracture is not all usable in forming, owing to necking. Nevertheless, true strain beyond that causing necking of an ordinary tensile specimen can be utilized, because most forming operations do not exhibit the unstable condition favouring necking on a tensile specimen.

In addition, an increase in temperature also increases

toughness, curves of toughness as a function of temperature being similar to those shown in Fig. 9 for toughness as a function of true strain rate. Although this increase in toughness with increasing temperature does not benefit slow forming methods such as hot-fluid forming, it benefits high-velocity forming methods considerably.

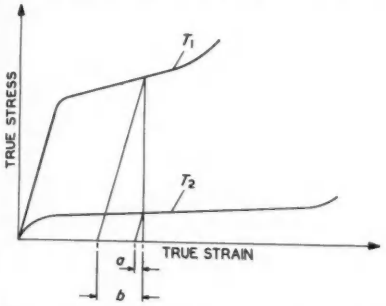


Fig. 10. True stress/strain curves, showing the spring-back *a* after creep-forming at an elevated temperature T_2, and the spring-back *b* after forming at the normal service operating temperature T_1.

Still another benefit derived from increased temperature is creep, i.e., the plastic deformation resulting in metals at stresses lower than slip[2]. An increase in temperature greatly accelerates creep, which is primarily a high-temperature phenomenon. Practical elevated-temperature creep-forming is generally accomplished in a period of less than 10 min and at a temperature which is approximately 500° F higher than the service operating temperature for the metal concerned.

The results of creep-forming are the elimination of such problems as buckling and distortions in the forming of thin-gauge sheet metal, and also the virtually complete elimination of spring-back, as shown in Fig. 10, in which *a* is the spring-back after creep-forming at an elevated temperature T_2, and *b* the spring-back after forming without the aid of heat at the normal service operating temperature T_1.

Hydrostatic Pressure

In discussing high-energy forming methods, an important theory is that connected with the effects of hydrostatic pressure on the ductility of metals. Thus, Bridgman[3] has shown that a high transverse hydrostatic pressure acting on a tensile specimen during pulling will exhibit a considerable increase in total true strain to fracture. In tests carried out on four tensile specimens, with applied transverse hydrostatic pressures ranging from 15 to 570,000 psi, the resulting true stress/strain curves showed that the flow stress does not change appreciably, but that the true strain to fracture increases with hydrostatic pressure. Also, the mode of fracture changes from a combination of ductile and brittle failure with a hydrostatic pressure below 170,000 psi to a totally ductile failure above this pressure. In these tests, it is of significance to note that the applied true tensile stress to cause flow was reduced from a value of approximately 300,000 psi with no hydrostatic pressure to slightly over 100,000 psi with a hydrostatic pressure of 570,000 psi. This type of increased ductility is very similar to the forward and back tension that increases fabricability when rolling sheet materials.

Many recent investigators working on high-velocity methods of forming have attempted to correlate hydrostatic pressure with formability, with very little success in obtaining any appreciable increase in actual elongation[4]. Some of the reasons for this lack of correlation can be determined from an analysis of Fig. 11.

When the part is being formed with a vacuum on the opposite side (Fig. 11a), the only resisting forces to the applied pressure are the resulting flow stress σ_R of the material and the inertia force *ma* of the moving mass *m*, where *a* is its acceleration. The inertia force *ma* is practically zero, so that there is virtually a zero net pressure acting hydrostatically in the transverse direction during flowing. The resulting Mohr's circle of true tensile stress σ and the resulting shear stress τ (Fig. 11b) shows that the explosive pressure *p* acts only to extend the part longitudinally, forming being accomplished by the resulting stress σ_R. The maximum shear stress τ_{max}, i.e., the radius of the circle, does not increase from the transverse pressure during forming.

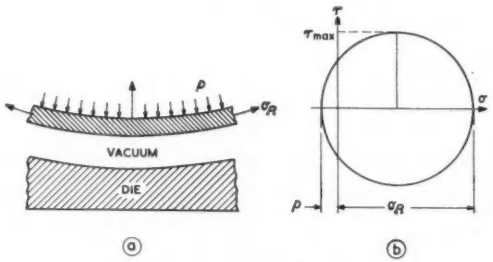


Fig. 11. Effect of hydrostatic pressure when forming a part with a vacuum on the opposite side.

After the part contacts the die, however, the hydrostatic pressure acts in a beneficial manner, though it does not benefit forming in the case of large-mass methods, even after the part has touched the die, because the pressure is so small. However, when the pressure exceeds the compressive flow stress of the material, as it often does in high-velocity methods of forming, the shear stress τ greatly increases, permitting a considerable increase in plastic flow. It is true that this high pressure is also lacking in high-temperature methods of forming, but the creep resulting from the heat allows the metal to flow to a considerable extent.

The net result in the case of both high-velocity and high-temperature methods of forming is an almost complete removal of the longitudinal stress σ_R by increased longitudinal flow, which acts to remove residual stresses tending to be set up and, in turn, minimizing spring-back and distortion. Spring-back and distortion can be removed in high-velocity forming operations only by means of a very high hydrostatic pressure acting transversely. Generally, this pressure must exceed the compressive flow stress by a considerable amount, because the high speed of forming tends to retard plastic flow inside the part away from the surface.

To be concluded

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A New High-Voltage Surge Recorder

By J. G. ANDERSON and R. U. GIACOMONI

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No. 46, February 1960,
pp. 1800–1808, 11 illustrations.

THERE are many occasions during investigations of high-voltage or high-current phenomena when it is desirable to make wave-shape and amplitude records of rapid surges whose times of occurrence cannot be predicted in advance. Typical examples include lightning surges to transmission lines and surges developed during switching operations or faults on power systems.

While it is recognized that oscillographs provide the most accurate way of recording high-voltage transient wave-shapes, a need also exists for a simpler and cheaper passive device requiring no power for its operation. The earliest such devices for surge measurements were the klydonograph, which was essentially a simple Lichtenberg-figure discharge recorder using photographic film, and the magnetic link. The klydonograph, when relying on only one Lichtenberg figure, had an accuracy of about 25% and could only give a very crude indication of voltage wave-shape. The magnetic link gave no wave-shape indication at all, recording only the maximum magnetic field occurring in the vicinity of the link. A great amount of data has been obtained from these two instruments or modifications of them, and they have produced most of the present information on the magnitudes of lightning surges on transmission systems. However, in recent years, the occurrence of very high lightning flash-over rates on transmission lines has emphasised the need for better instrumentation for the determination of stroke-current wave-shape.

After an intensive investigation, a new instrument designated the "teinograph", has been developed, in which an incoming high-voltage surge is stretched out in space or time and is "written down" as a sequence of Lichtenberg-figure discharges. The envelope of these discharges describes the wave-shape of the surge and, depending on the kind of dielectric material on which the discharges are created, the records can be made either permanent or temporary. Laboratory tests on this instrument show that it has considerable promise, and field tests are now in progress to gain further experience.

Several circuit variations of the teinograph are possible, these variations falling into one of two distinct classes, i.e. space-sequential and time-sequential. The time-sequential type is somewhat simpler in operation, making a sequence of Lichtenberg-figure records of the voltage magnitude of a surge at successive intervals of time. Its mode of operation is shown in Fig. 1, in which a changing voltage (Fig. 1a) is impressed between the conductor AA' and earth B. Connected to AA' is a group of point-to-plane electrodes with a dielectric inserted between each point P and the plane, and with the point tied to AA' through resistors R. As long as the switches S are open, no voltage can appear across the electrode assemblies. If, however, at a time t_1, switch S_1 is closed, a voltage equal to the sum of the constant voltage V_0 (of opposite polarity to V), and the changing voltage V at that instant is produced between point P_1 and its plate. Lichtenberg discharges will spread across the dielectric at P_1 ,and the diameter of the discharge pattern will be proportional to the sum of the

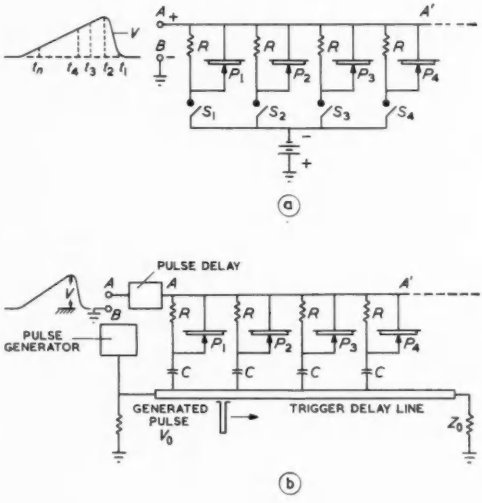

Fig. 1 (above). Time-sequential teinograph, showing (a) the basic principle, and (b) the circuit for fast surges.

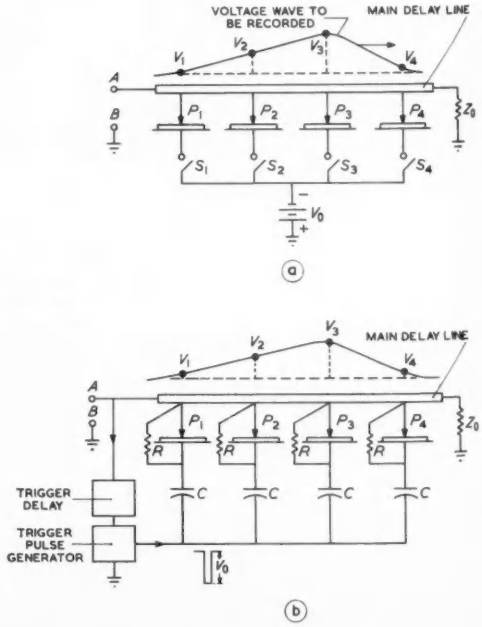

Fig. 2 (right). Space-sequential teinograph, showing (a) the basic principle, and (b) the circuit for fast surges.

two voltages at that instant. If switch S_1 is then opened immediately, the pattern diameter cannot change, and, knowing the magnitude of the "trigger voltage" V_0, the value of V at time t_1 can be readily determined from pattern measurements. In some cases V_0 can be made zero but, since Lichtenberg figures generally must have a voltage of at least 2 kV in order to form, a "bias" voltage of this value is helpful, provided that the polarity of the surge to be measured is known in advance. If switches S_2, S_3, etc. are then closed momentarily at times t_2, t_3, etc. respectively, records of the voltage V at these discrete times can also be recorded. In this manner, a record of the wave-shape of V can be obtained as a sequence of Lichtenberg figures.

For the time-sequential teinograph, the operation of switches S can be either mechanical or electrical, depending on the speed desired. Slowly changing voltages having periods of several thousand microseconds (such as some switching surges) may only require mechanical switching. However, mechanical operation of the switches in Fig. 1a is not practical when microsecond surges are to be measured, and other means must be used. One such approach is shown in Fig. 1b, in which the incoming surge is delayed by about 1 microsecond before being applied to the conductor AA'. The voltage wave is also fed to a pulse generator (a step-up pulse transformer and spark-gap arrangement) whose output is a high-voltage surge having a polarity opposite to that of the surge to be measured and a duration of a fraction of a microsecond. This generated pulse V_0 travels down a trigger delay line towards the line termination Z_0, and at successive intervals of time is applied to points P_1, P_2, . . . P_n through capacitors C. Prior to and immediately following the appearance of this pulse at any electrode P, the voltage between P and its plate attached to AA' will be too low for Lichtenberg figures to form, provided that the ratio of R and Z_0 is properly set. Thus, Lichtenberg figures will form only at the instant that the generated pulse V_0 arrives at the point electrode to pull this electrode down in potential, and the figure diameter will be proportional to the sum of the voltage V_0 (of opposite polarity to V) and the signal voltage V at that time. This is exactly the same result as in the case of Fig. 1a, where mechanical switching was employed, but at a much higher speed.

In practice, the circuit of the time-sequential teinograph in Fig. 1b is difficult to construct. The trigger delay line must often be several microseconds in length and must carry high-frequency pulses of several kilovolts and of a duration of only a fraction of a microsecond. Since this measuring technique is essentially a voltage-sampling scheme, the duration of the trigger pulse must be less than that required for any appreciable changes in the sampled voltage to occur. Also, the trigger voltage V_0 must be generated as soon as possible after arrival of the surge to be measured, and the signal V must be delayed by a pulse-delay circuit until this triggering can occur.

Because of the extreme requirements of the trigger delay line characteristics, the space-sequential teinograph has been developed. The space-sequential teinograph differs from the time-sequential type in that it spatially distributes a wave to be measured along a delay line and then, at some suitable time, samples the voltage to earth at every point along the line simultaneously. The basic principle is shown in Fig. 2a, in which the incoming voltage V is applied to a main delay line, terminated in its characteristic impedance Z_0. After a suitable interval of time, V will have travelled along the line to the position shown in Fig. 2a. Connected to this line are the same Lichtenberg-figure recorders as in Fig. 1a, and the same switches. No discharge records will be obtained as long as switches S_1, S_2, etc. are open. If, when the wave has reached the position shown, all the switches are closed simultaneously for a fraction of a microsecond and then reopened, the Lichtenberg discharge pattern formed around P_1 will be proportional to V_1+V_0, that at P_2 will be proportional to V_2+V_0, etc. If enough recorders are used, a complete record of the wave-shape at the instant the switches are closed will be obtained.

As, in Fig. 1a, mechanical switching cannot be used for fast surges, a circuit for this purpose, using exactly the same parts as in Fig. 1b, is shown in Fig. 2b. It will be seen that the trigger delay line in Fig. 1b becomes the main delay line in Fig. 2b, and the pulse delay, instead of delaying the signal to be measured, now delays initiation of the trigger pulse until the voltage V to be measured has penetrated to a point almost at the end of the main delay line, when pulse V_0 is formed. This pulse initiates the same type of Lichtenberg figures described for the configuration in Fig. 2a, and the wave-shape is recorded. This circuit has the advantage that the main delay line need have a frequency response which is only sufficient to pass the surge to be measured, whereas, in the case of the circuit in Fig. 1b, a delay line is required with the same electrical length but with an upper frequency response which is almost ten times higher, in order to pass the very rapid trigger pulse.

In some models of the space-sequential teinograph, certain compromises have been made to reduce cost and to facilitate construction. These compromises have taken the form of not dividing the plates of the Lichtenberg-figure recorders into separate parts and of having the equivalent of only one resistor R and capacitor C. The resulting circuit is shown in Fig. 3 for a 5-microsecond device used to measure the wave-shape of the fronts of lightning-current surges. All the Lichtenberg-recorder plates have now been tied together to become one plate, and the multiplicity of capacitors C has become one capacitor C_3. Similarly, all the resistors R have become one resistor R_1, and this resistor is connected to the input end of the delay line instead of to each point electrode. The wave penetrates along the main delay line as before and, as it propagates, it develops some voltage between each of the points P and the metal trigger plate, since the latter is held at a potential part of the way between line and earth, by resistors R_1 and R_2. Some discharge figures may appear around the points P before and after triggering, but, for lightning wave-fronts, analysis has shown that, provided that R_2 is considerably larger than R_1, these discharges are either small or of opposite polarity from those appearing during the triggering process. As a result, they do not usually interfere with the record.

The same incoming surge to be measured also passes through the trigger delay line and, after a time interval, arrives at the pulse transformer T. As soon as the wave arrives, it is inverted in polarity and is greatly amplified by the transformer-turns ratio. Capacitor C_4 then charges up rapidly, and, at about the time that the surge to be measured has almost reached the line termination Z_0, the voltage across C_4 reaches a value sufficient to spark over the gap G. Capacitor C_4 then discharges into the low resistance R_3. The voltage across R_3 immediately reaches a value V_0 of about 15 kV and of opposite polarity to the measured wave, but, because of the short

C_4R_3 time-constant, falls off rapidly in a fraction of a microsecond to a low value, this being the triggering pulse previously described. This pulse pulls the triggering plate down in potential through C_3, and the discharge around each point P at this instant becomes proportional to the sum of the trigger voltage V_0 and the potential on the main delay line at that point.

In practice, the housing of the space-sequential teinograph is normally covered with aluminium foil for shielding purposes. As the device is essentially a single-surge recorder, it has in its input end a special gap mechanism which, when the first surge appears, explodes a small explosive gap that short-circuits the recorder input after about 1 millisecond, preventing subsequent surges from obliterating the record made by the first surge. The same gap mechanism is also arranged in such a way that, once the door of the teinograph housing is opened, it cannot be closed unless an unexploded gap is in place, thus reminding the operator to insert such a gap in the circuit before a measurement is made. Small phosphor-bronze fingers are connected to each coil and serve as the points P in Fig. 3. The pulse transformer and trigger circuit are located behind the main delay line.

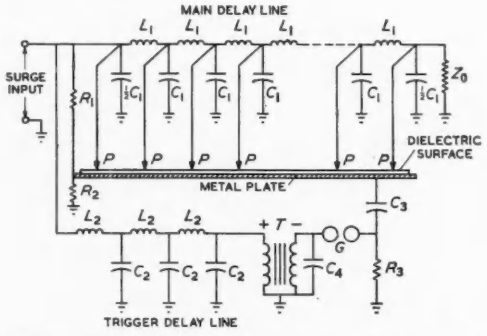

Fig. 3. Modified circuit used in practice in a 5-microsecond space-sequential teinograph.

Recording can be effected in two ways, i.e., by a "powder" method or photographically. In the powder method, a thin Lucite plate is inserted between the metal trigger plate and the points P, the discharges from the points spreading out over the surface and depositing a pattern of surface charge at each streamer location. If the plate and the air inside the teinograph are kept dry by means of a tightly sealed housing and a desiccant, this charge pattern can be retained for as long as a week or more, and can be "developed" by a light dusting with fine talc. This method has the advantage that it is insensitive to light and needs no chemical processing.

A series of tests comparing the recording capabilities of the Lucite plate with photographic film so far indicate that the recording sensitivity of the film is more constant. To take advantage of this consistency and to permit records to be made which will not fade away, a photographic-film packet has been devised for inserting into the same location as the Lucite plate. Electrodes, embedded in the packet and touching the film inside it, make contact with the phosphor-bronze fingers during insertion into the teinograph. This packet can be inserted in the teinograph during daylight hours and retains its record for a year or more.

Any teinograph using a Lichtenberg-figure recording method must have an input of at least 5 kV to form reasonably sized figures. To construct lightning shunts with this magnitude of output voltage and to take the full energy of a long-duration lightning stroke would be prohibitively expensive if a large number of recorders is to be used. Consequently, some transducer other than a shunt is necessary in such applications as measuring lightning surge currents on transmission-line tower tops, and this problem has been solved by the development of a current pick-up coil connected to the input end of the teinograph. As the stroke current travels down the tower lightning-rod, it creates a magnetic field which is proportional to the current. This magnetic field links the pick-up coil and, if the output load R_s across the coil were high, would produce an output voltage proportional to the time derivative of the current. However, if the value of R_s is kept low and if sufficient turns are used on the coil, the coil inductance and resistance R_s form an integrating circuit, so that the output voltage is proportional to the current amplitude, instead of the current derivative. Tests have shown that a single-layer wound coil, 8 in. long by 3½ in. wide, can be built with an output of 20 kV for a rod surge current of 100 kA, if it is loaded down with a terminating resistance R_s of 135 ohms. Thus, the coil and termination act as a 0·2-ohm shunt and have a transient response completely satisfactory for waves cresting in 1 microsecond or more. For waves with front times of 0·6 microsecond, some distortion of the front of the output voltage is noted.

Limited experience indicates that, for lots of twenty or more teinographs, manufacturing costs will be from 10% to 50% that of equivalent oscillographs, depending on the desired elaborateness of the device, the writing time, and the particular application. Laboratory models weigh about 22 lb and measure $18\frac{1}{2} \times 10 \times 6\frac{1}{2}$ in., but these figures are by no means the minimum possible.

Further laboratory tests are being made on improved teinograph designs. Thus, twenty recorders, complete with current pick-up coils, have been constructed and have been installed on approximately 5 miles of 345-kV transmission line, one recorder on each tower. From the experience gained on these first models, it is hoped that the instrumentation can be advanced to the point where a wealth of needed information on surge magnitudes and wave-shapes can be obtained in the near future.

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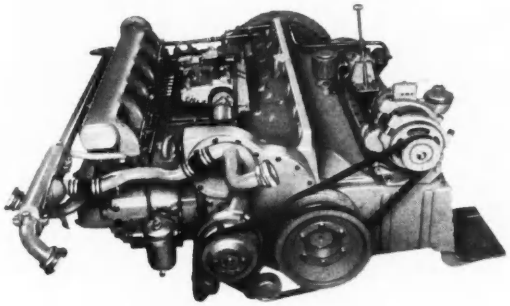

081 MAe

Mercedes-Benz Diesel engines, in common with all the products of Daimler-Benz, are world-famed for their high performance, economy, sturdy construction and dependability. They have additional advantages which are of particular importance in their use for rail transport: they take up little space, they are light and need little and infrequent attention. The range of Daimler-Benz Diesel engines consists of 34 models up to 1900 PS. This range offers suitable power units for every type of locomotive, for shunting and for drawing express or goods trains, for rail buses and high speed railcars.

Types and Performance Data Type	Cooling	No. of cylinders Arrangement	Output PS (DIN)	Speedrange R. P. M.	Cyl. Bore ins.	Stroke ins.	Piston displacement cu. ins.	Weight approx. lbs.
M 202 B	W	2/S	35 – 55	750 – 1200	5 1/2	8 1/4	394.8	1665
M 203 B	W	3/S	54 – 90	750 – 1200	5 1/2	8 1/4	591.9	2150
M 204 B	W	4/S	72 – 120	750 – 1200	5 1/2	8 1/4	789.0	2715
OM 636	W	4/S	17 – 35	1500 – 3000	2 15/16	3 15/16	107.8	495
OM 312	W	6/S	47 – 77	1500 – 2400	3 9/16	4 3/4	279.5	784
OM 321	W	6/S	55 – 94	1500 – 2600	3 3/4	4 3/4	311.2	784
OM 315	W	6/S	80 – 124	1200 – 1800	4 7/16	5 1/2	505.0	1700
OM 326	W	6/S	97 – 155	1200 – 1800	5 9/64	5 1/2	660.0	1720
MB 851	W	1/S	9 – 20	1000 – 2000	4 1/2	5 1/2	88.8	662
MB 861	L	1/S	9 – 20	1000 – 2000	4 1/2	5 1/2	88.8	662
MB 852	W	2/S	18 – 40	1000 – 2000	4 1/2	5 1/2	176.9	915
MB 862	L	2/S	18 – 40	1000 – 2000	4 1/2	5 1/2	176.9	915
MB 853	W	3/S	27 – 60	1000 – 2000	4 1/2	5 1/2	266	1122
MB 863	L	3/S	27 – 60	1000 – 2000	4 1/2	5 1/2	266	1122
MB 854	W	4/V	36 – 80	1000 – 2000	4 1/2	5 1/2	354.4	1245
MB 864	L	4/V	36 – 80	1000 – 2000	4 1/2	5 1/2	354.4	1245
MB 846 A	W	6/S	114 – 250	750 – 1500	5 7/8	7 1/2	1230.2	3860
MB 846 B	W	6/Li	114 – 250	750 – 1500	5 7/8	7 1/2	1230.2	3970
MB 846 Ab ▽	W	6/S	148 – 320	750 – 1500	5 7/8	7 1/2	1230.2	4080
MB 846 Ad ▼	W	6/S	148 – 320	750 – 1500	5 7/8	7 1/2	1230.2	4200
MB 846 Bb ▽	W	6/Li	148 – 320	750 – 1500	5 7/8	7 1/2	1230.2	4200
MB 836 B	W	6/S	240 – 375	1000 – 1500	6 7/8	8 1/16	1806.3	4380
MB 836 Bb ▽	W	6/S	320 – 525	1000 – 1500	6 7/8	8 1/16	1806.3	4830
MB 836 Db ▼	W	6/S	370 – 650	1000 – 1500	6 7/8	8 1/16	1806.3	5050
MB 820 B	W	12/V	460 – 750	1000 – 1500	6 7/8	8 1/16	3612.6	6180
MB 820 Bb ▽	W	12/V	640 – 1100	1000 – 1500	6 7/8	8 1/16	3612.6	6900
MB 820 Db ▼	W	12/V	770 – 1350	1000 – 1500	6 7/8	8 1/16	3612.6	7240
MB 837 A	W	8/V	165 – 440	1000 – 2000	6 1/2	6 7/8	1825	2940
MB 837 Aa ▽ ▽	W	8/V	215 – 550	1000 – 2000	6 1/2	6 7/8	1825	3020
MB 835 Ab ▽	W	12/V	840 – 1450	1000 – 1500	7 1/2	9 1/2	4773	8157
MB 835 Bb ▼	W	12/V	1015 – 1780	1000 – 1500	7 1/2	9 1/2	4773	8597
MB 839 Ab ▽	W	16/V	1120 – 2000	1000 – 1500	7 1/2	9 1/16	6380	11020
MB 839 Bb ▼	W	16/V	1350 – 2400	1000 – 1500	7 1/2	9 1/16	6380	11450
MB 518 B ▼▼	W	20/V	3000	1720	7 5/16	9 13/16	8201.5	10550

Note:
W = water cooling · L = air cooling
Li = horizontal · S = vertical
V = vee type · ▽ = with exhaust-turbo-supercharging · ▼ = with exhaust-turbo-supercharging and boost intercooling · ▽▽ = with mechanical supercharging · ▼▼ = with mechanical supercharging and boost intercooling

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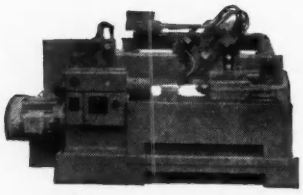

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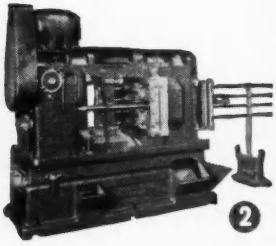

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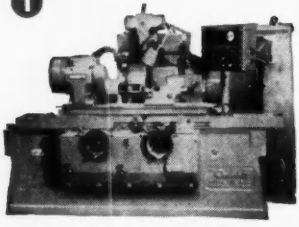

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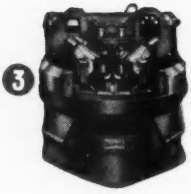

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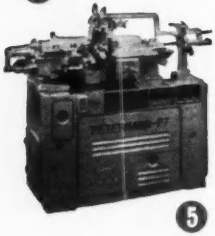

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INTERNATIONAL MACHINE TOOL EXHIBITION, 1960

Covering a total area of about 350,000 *sq ft, of which nearly* 300,000 *sq ft represent the stand space occupied by about* 300 *stand-holders, the International Machine Tool Exhibition will be held at Olympia, London, between June* 25 *and July* 8. *Of the total number of exhibitors, about* 110 *will display British-built metal-cutting or metal-forming machine tools, foreign machines being shown on the stands of* 45 *importing members of The Machine Tool Trades Association, who are the organizers of the exhibition. Of the total of roughly* 1400 *machine tools to be exhibited, approximately* 60% *are of British manufacture, as compared with about* 65·5% *for the previous exhibition held in* 1956. *In addition to machine tools, the exhibits of allied trades, including heat-treatment furnaces, welding equipment, small tools, jigs, gauges, etc., will also be well represented by* 95 *exhibitors of such equipment.*

Catmur Machine Tool Corporation Limited

An extremely wide range of exhibits is to be presented by the Catmur Machine Tool Corporation, of London, W.11, including Barnaby standard bandsaws, Upam inclinable vertical metal-cutting bandsaws, Clark automatic press feeds, and Hommel centreless cylindrical lapping machines and optical grinding machines. Other exhibits will include examples of Moore jig grinding machines, Eichler vertical milling machines, Rosenfors universal milling machines, Bridgeport turret milling machines, Van Norman universal milling machines, and Korradi universal milling machines, together with a very wide range of Steinel equipment, including tapping machines, drilling machines, riveting machines, and vertical and horizontal milling machines.

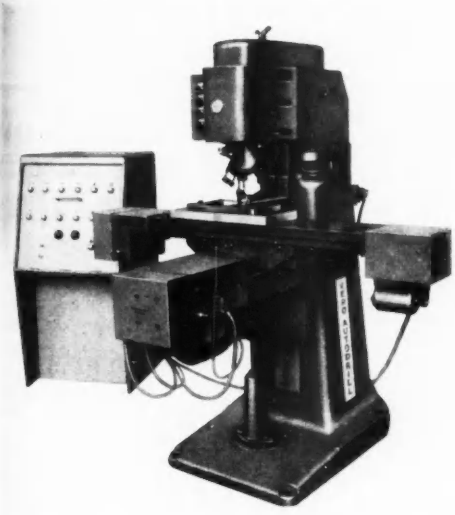


Fig. 1

A particularly interesting exhibit will be the Vero "Auto-Drill", which is constructed by Vero Precision Engineering Ltd., of Southampton, and marketed exclusively by Catmur. This machine (Fig. 1) is the world's first programmed turret-head drilling machine with purely electical control, and is also the first machine of its kind which is capable of drilling and tapping a pattern of up to 600 holes in six different sizes in any order without human intervention, this being achieved by controlling both the work position and the six-spindle turret head entirely automatically from a punched tape. The wide range of drill sizes and spindle speeds provided, combined with the versatile control system used, enables this machine to be employed usefully in almost any light-engineering machine shop. Thus, on automatic control, its economic applications include the drilling of castings, plates, cabinets, printed circuits, etc., in any quantity from about twelve upwards. When manually controlled, it can speed up the production of components produced in smaller quantities and the manufacture of templates.

The drilling machine is fitted with a 32×9 in. co-ordinate table having a longitudinal traverse of 24 in. and a cross traverse of 12 in. The positioning speed is 60 ipm, and an overall drilling accuracy of $\pm 0{\cdot}003$ in. is guaranteed. The turret head is fitted with six chucks for accommodating drills of up to $\frac{5}{16}$ in. in diameter, and spindle speeds from 300 to 6000 rpm are provided. The maximum distance from the spindle to the table is 20 in.

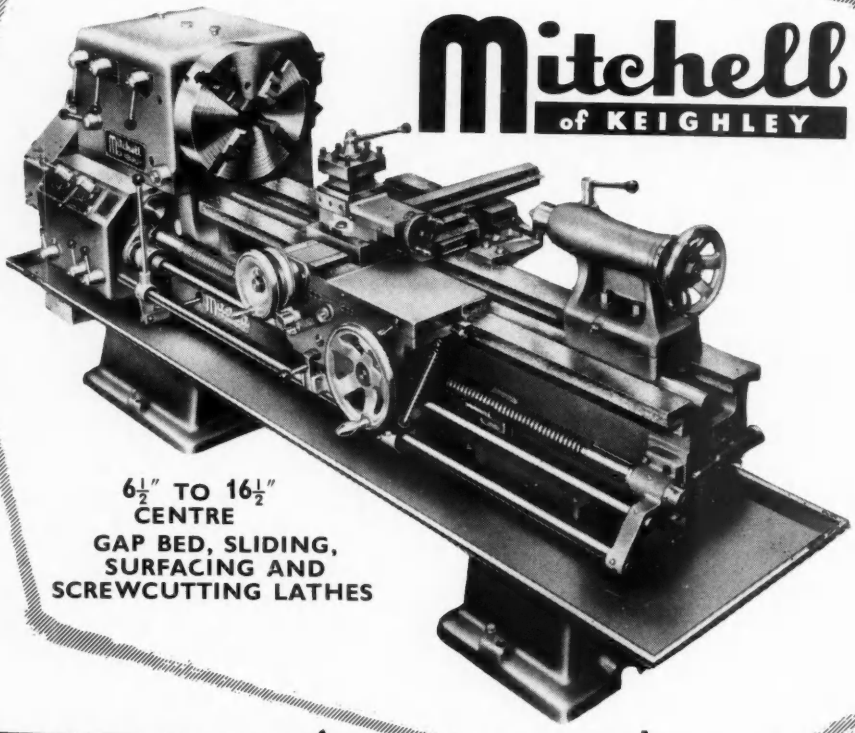
The control system, which is manufactured by Airmec Limited, of High Wycombe, operates by measuring very accurately the total angular rotation of the leadscrews, a function performed by a positioner unit consisting of a series of commutator-type switches. Manual operation, if required, is performed from a control panel, and automatic drilling is controlled by a plastic tape carrying information for complete drilling or tapping operations.

The outstanding feature of the control system is that it is purely electro-mechanical (rather than electronic) in nature, no valves being employed and operation being achieved by 24-V d.c. switching circuits, so that maintenance and servicing can be effected by normal works electrical staff. Another particular feature of the system is that the positioner unit measures absolute angle and not change of angle, as in many impulse systems. Consequently, after any interruption or mains failure, the table automatically positions correctly, and no re-zeroing is necessary.

The Newall Engineering Co., Ltd.

A comprehensive cross-section of exhibits from the Newall organization, of Peterborough, will include representative examples from their range of jig boring machines, Newall-Keighley grinding machines, and

Mitchell of KEIGHLEY



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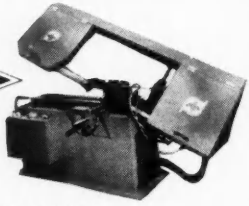
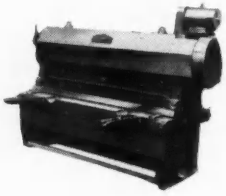


METAL CUTTING BANDSAWING MACHINES

RUSHWORTH of SOWERBY BRIDGE

PLATE BENDING ROLLS
GUILLOTINES, PRESS BRAKES



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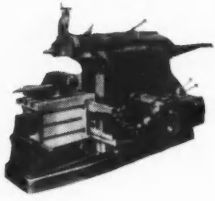
HEAVY DUTY LATHES AND SHAPING MACHINES



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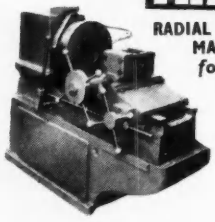

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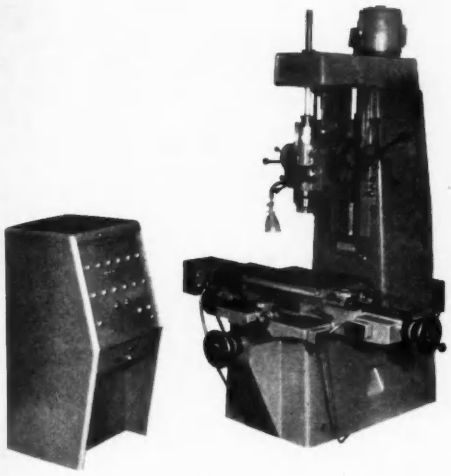


Fig. 2

optical inspection and pneumatic gauging equipment.

In addition to the "Spacematic" Model 2657, which has been designed specifically for automatic control and which incorporates the B.T.H. measuring and control system, exhibits of jig boring machines will include the Model-2443 machine and the Model-1520 CC jig boring and milling machine with A.E.I. "Helixyn" control, which affords continuous numerical control of three movements. This machine is being demonstrated to show the many advantages and production facilities provided by this type of automatic control, which is manufactured by the Electronic Apparatus Division of Associated Electrical Industries Limited.

Still another exhibit in this category is the "Spacematic" Model-1520 jig boring and milling machine (Fig. 2), which is an auto-positioning model of the standard Model-1520 jig boring machine, with the same capacity and general characteristics. However, in addition to either the Newall roller or optical system, enabling table settings to 0·00005 in. to be made, the machine is also requipped with the Airmec automatic measuring and control system, which gives greatly improved production times when an overall accuracy of 0·0005 in. is adequate. Thus, the machine has the dual role of catering for the highest-accuracy jigs and components by using the manual setting system, and for increased productivity in the more numerous cases where somewhat lower accuracy can be tolerated. The robust and extremely reliable control equipment is contained in a cubicle requiring little floor space, co-ordinates being selected by manual setting dials or by punched tape. Useful supplementary features of the machine are the addition of a rapid power traverse to the cross-slide and table milling feeds of 0·6, 2·4, and15 inches per minute.

The comprehensive range of Newall-Keighley grinding machines on show will cover conventional, special-purpose, and automatic units, including the Model P.N.L. auto-cycle plunge-grinding machine, which is a completely new development designed for plunge-grinding regular and irregular profiles of concave or convex form to extremely close tolerances at fast production rates. An automatic diamond dresser, controlled from the operator position, provides for a $\frac{7}{16}$-in. maximum depth of form. Radial movement of the worktable, which is supported on fulcrum rollers, provides controlled grinding in-feed and rapid withdrawal of the workpiece from the grinding wheel. The work cycle is operated by a single lever after initial setting up, and the tailstock automatically moves into position to locate the component in the holding fixture under a predetermined hydraulic pressure.

Other exhibits in this section include a range of cylindrical grinding machines, angle-head grinding machines, internal grinding machines, universal grinding machines, lapping machines, and fine-boring machines, as well as the Model B.G. bearing grinder, the Model ANL automatic tap-grinding machine, and the Model MAC multi-wheel grinding machine. The Model B.G. bearing grinder is a newcomer to the range of Newall high-precision grinding machines and has been developed for production-grinding the radiused tracks of ball-bearing inner races and similar components to a high order of accuracy.

The Model ANL automatic tap-grinding machine is a totally enclosed, fully automatic, high-speed quantity-production machine designed for grinding taps up to $\frac{1}{2}$ in. in diameter or other threaded components of similar size, the capacity of the machine being 12 in. between centres. After initial setting up, the machine is controlled by a single push-button, the sequential control being electrical, while electro-pneumatic operation with solenoid valves is fitted to the tailstock spindle and work-feed magazine. Other notable machine features include a built-in temperature control for the spindle-lubrication system to ensure accurate sizing of the grinding wheel, an automatic pantograph diamond dresser or wheel crusher, and an automatic sizing gauge which functions at previously established intervals and at the end of every wheel forming cycle. The work-feed mechanism consists of an electrically and pneumatically operated feed unit and drum-type magazine, into which up to 36 tap blanks can be spring-loaded. The magazine is designed to ensure that, when taps are fed into the machine, correct relationship is established between the

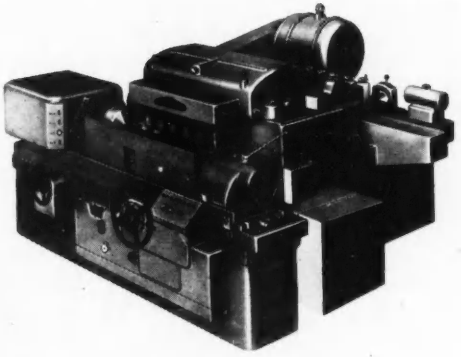
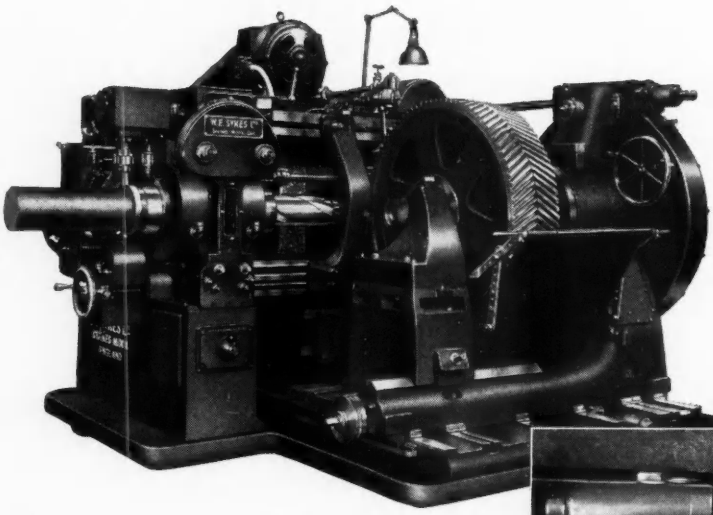


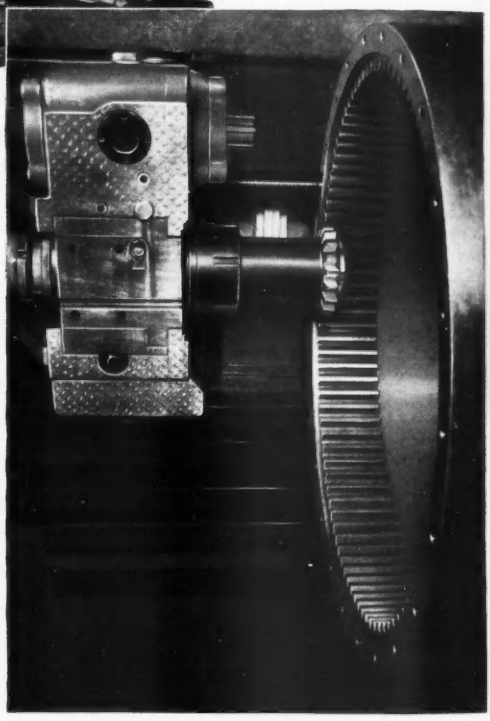
Fig. 3

flute and wheel for relief-grinding. The indexing mechanism of the feeder unit is automatically interlocked with the machine grinding cycle. The machine motions, which are fully automatic, provide a cycle of feeding a tap into the work drive; locating, grinding and ejecting it; and gauging and dressing. The cycle repeats until the



Capacity 63 in. blank diameter, 16—1½DP, 18 in. face width.

A sound investment



For the larger, heavy duty gears there is no better investment than the Sykes Model 5E Horizontal gear generating machine. It is capable of producing—to the highest standards of accuracy —spur, helical or double helical gears in addition to a wide range of Internal gears and forms.

Ease of setting, simplicity of operation and robust construction make it equally profitable on small batch or large scale production. Even more important, the high initial precision of the Model 5E machine is maintained unchanged throughout its exceptionally long life.

STAND N° 108

Talk to SYKES about gear production

W. E. SYKES LIMITED · STAINES · MIDDLESEX · ENGLAND and associated companies: Sykes Tool Corporation Ltd., Georgetown, Ontario, Canada. Sykes Machine & Gear Corporation, Newark, NJ, USA. W. E. Sykes Ltd., Mascot, Sydney, NSW., Australia

magazine is empty, when the machine stops and both visible and audible signals are given to indicate that reloading is necessary.

The Model MAC multi-wheel grinding machine (Fig. 3), another newcomer to the Newall manufacturing programme, has a 12-in. maximum swing and 40-in. capacity between centres and is designed to grind in one operation components having a number of diameters, such as crankshaft and camshaft journals. The wheel-spindle, which will accept 36-in. diameter grinding wheels over a maximum span of 32½ in., is supported at each end in cartridge-type bearings and is driven by a 30-hp wheelhead-mounted motor. Truing of the grinding wheels is effected by a hydraulically operated dresser mounted on the wheelhead, each wheel being dressed by a separate diamond, controlled from the front of the machine. The wheelhead is equipped with a rapid-approach and withdrawal movement which can be varied to suit the type of workpiece, and is provided with three feed rates for roughing, finishing, and, for use where necessary, an ultra-fine ratchet or intermittent feed. The heavy-duty, dead-centre workhead is driven through Vee-belts by a 2-hp motor.

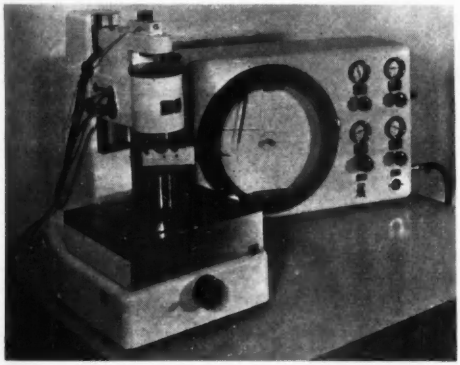


Fig. 4

Exhibits of optical inspection and pneumatic gauging equipment, made by Optical Measuring Tools Ltd., of Maidenhead, one of the Newall group of companies, will include optical rotary tables, automatic indexing rotary tables, optical comparators, optical dividing heads, toolmakers' microscopes, projectors, and air-gauging and automatic machine-control equipment. A particularly interesting exhibit in this category is an entirely new roundness measuring machine which provides facilities for measuring roundness to an extremely high order of precision. This machine (Fig. 4) comprises a bearing in which a spindle carrying a gauging pick-up is rotated at 1 rpm. The pneumatic-type pick-up bears a spring-loaded controlling stylus to contact the periphery of the work and, as the spindle is rotated, the stylus moves around the periphery and produces a signal in the pick-up head. This signal is amplified and fed to a circular chart recorder producing an accurate record of roundness. To obtain a high degree of concentricity and low frictional torque, an air bearing, requiring a working pressure of 60 psi, is used. Concentricity with this bearing is maintained to within 0·000005 in. The magnification obtained with the instrument is 1000 or 5000, change-over being effected by rotating a small knob on top of the bearing unit. At a magnification of 5000, a radial space of 0·05 in. on the recorder chart represents 0·00001 in. The measuring range of the unit for internal diameters is from $\frac{1}{8}$ to 6 in., and for external diameters from $\frac{1}{16}$ to 6 in.

The Gear Grinding Co. Ltd.

A wide range of "Orcutt" machines, many of them new, will be shown by The Gear Grinding Co. Ltd., of Solihull, Warwickshire, including an internal helical gear grinding machine, a 48-in. gear grinding machine, individual base-circle involute measuring machines, a lead-measuring machine, and an automatic dividing engine, suitable for fitting to jig borers or drilling machines, in which automatic indexing of any combination of divisions is effected from paper-tape control from a console unit.

Other exhibits will include "Orcutt" hydraulic spline-shaft grinding machines, fitted with new hydraulic equipment, and the "Orcutt" automatic spur-tooth gear grinding machine. Of the spline-shaft grinding machines, both models, i.e., the 20-in. and the 36-in., now incorporate Vickers hydraulic equipment. The index head also incorporates two new additions, these being the Vickers hydraulic motor for increased power, and a new improved rolling device, which centralizes the component tooth space to the grinding wheel. The Vickers equipment includes an external pump unit, together with all reversing control-valves, speed control-valves, and hydraulic cylinder. An "Orcutt" hydraulic spline-shaft grinding machine is illustrated in Fig. 5.

The latest model, i.e., the G.A.7, of the "Orcutt" automatic spur-tooth gear grinding machine (Fig. 6) incorporates the latest form of single-diamond root trimmer, the diamond arm, into which a single diamond is mounted, being free to rotate in bearings in its housing in a horizontal carriage. This carriage is traversed by friction-free slides by a hydraulic cylinder, its engagement being provided through rack teeth in the piston rod and a gear on the diamond arm. It will therefore be appreciated that, if the movement of the slide is restricted, the diamond arm will rotate. In practice, micrometer stops are provided to control both the horizontal movement of the carriage and the arc of rotation of the diamond arm at both ends of the stroke. In addition, electrical limit-switches reverse or stop the system. In this way, it is possible to control extremely accurately the complete generation of root form and its blend into the involute form on the grinding wheel. In addition to complete

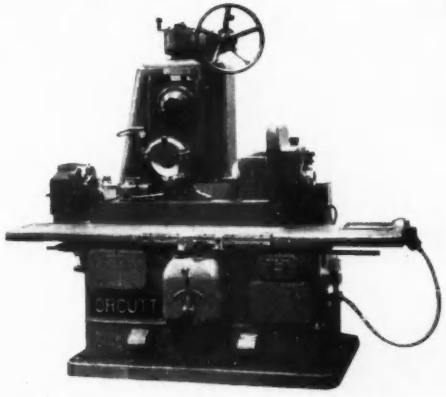


Fig. 5

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FRANKFURT (MAIN), Am Hauptbahnhof 6
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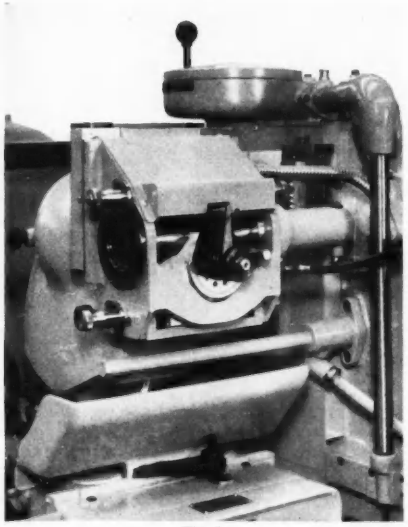


Fig. 6

control of root trimming and ease of setting both dimension and bend into involute form, advantages of the G.A.7 model with the new root trimmer include completely symmetrical form, better surface finish through improved speed control, simple micrometer adjustment for diamond wear, and entirely automatic operation.

David Brown Industries Limited

The David Brown Machine Tool Division of David Brown Industries Limited, Manchester, will feature as principal exhibits a number of gear-producing and gear-finishing machines, with a production capacity ranging from small gears to gears of 140-in. diameter. Part of the display will be devoted to illustrating the latest developments in the production of ultra-precision large-diameter gears, while another part will demonstrate recent advances in achieving high production rates for smaller gears, with particular reference to the automobile industry. In this connection, a No. 10 "Hydrax" production gear-hobbing machine, incorporating a number of recent developments, will be exhibited, in conjunction with the latest David Brown S.12.H production gear-shaving machine. Both these machines will be equipped with the latest David Brown "Multimatic" loading equipment, and will be used to demonstrate the production of automobile gears, which will first be hobbed and then shaved. Some of the latest David Brown gear-measuring equipment, as well as a selection of gear-cutting tools, including hobs and shaving cutters, will also be shown.

Two new David Brown machines, both of which incorporate a number of new and advanced developments and which will be exhibited for the first time, are the PH.30 ultra-precision gear-hobbing machine and the MH.140 ultra-precision turbine-gear-hobbing machine. The PH.30 machine (Fig. 7), which is capable of producing gears up to 30 in. in diameter, incorporates the N.E.L. diffraction-grating system for checking and controlling the transmission accuracy of the table drive. In this accuracy-control system, which is fully automatic, a circular diffraction grating with 21,600 radial lines is mounted inside the table, and another grating with 180 lines is mounted on the worm-drive shaft. The ratio of the number of lines is the same as the gear ratio between these two parts, so that the lines pass given stationary points near each grating at the same frequency.

Errors in the transmission of the table drive will cause the lines on one grating to advance or retard, compared with the lines on the other. By means of a light-source on one side of each grating and a reference grating and photo-electric cell on the other, sinusoidal electric signals are derived from each unit when the machine is running. By comparing the phase of these signals, the errors of the table transmission are measured. The error signal is then amplified and utilized in a feedback to impose fine correction to the transmission through a servo-correcting mechanism. Consequently, the accuracy is built into the machine and will never vary as a result of mechanical wear. The measuring system has an accuracy of ± 1 sec of arc, corresponding to 0·00015 in. on a 30-in. diameter gear.

The MH.140 ultra-precision turbine-gear-hobbing machine (Fig. 8) has a maximum capacity of 140-in. gear diameter, and is equipped with the "Emisyn" control system, which is designed to provide a continuous check on indexing accuracy and also to compensate for cumulative errors. The basic measuring elements of this system are a resolver, which is a signal generator driven by the worm-drive shaft coming from the main gearbox, and an Inductosyn. As described in our Survey of numerically controlled machine tools, the Inductosyn essentially consists of a stator and a rotor, each being a glass disc with a silver pattern on one face. The pattern on the rotor forms a continuous printed-circuit type of coil with 360 radial lines, the two ends of which are connected to the control console through a slip-ring and brush unit. The pattern on the stator has 16 sections, each comprising a printed-circuit type of coil of 16 radial lines.

The resolver produces an electrical signal representing the rotation of the worm-drive shaft. This rotation is also transmitted to the table in the form of rotation or a "mechanical" signal, but includes errors introduced by the gears and the master worm and wormwheel. Consequently, when the electrical and mechanical signals are compared at the Inductosyn, the difference represents the

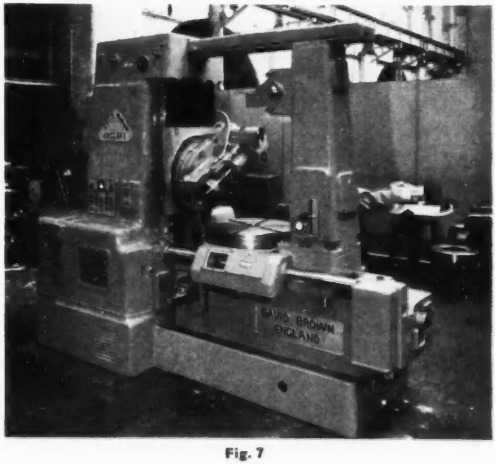
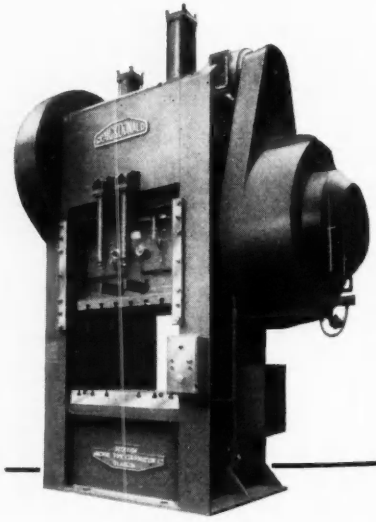


Fig. 7



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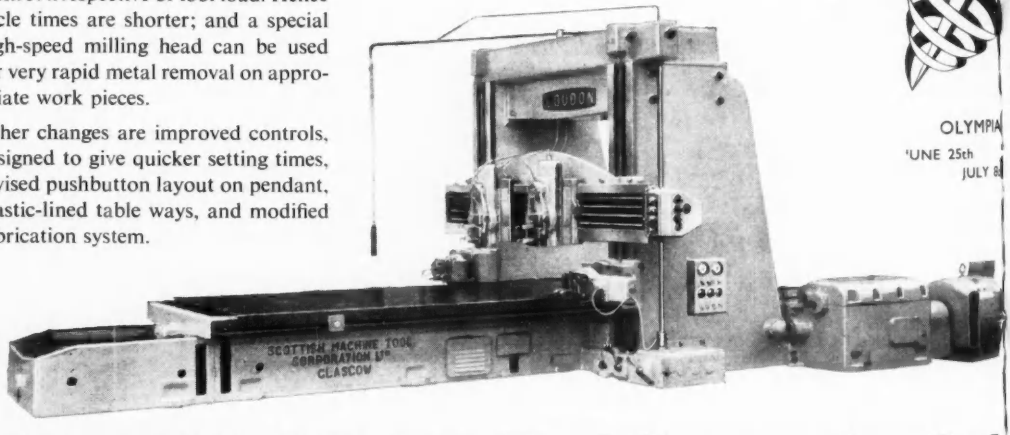
heavy duty planing machines

Recent developments in these modern planing machines include a new closed loop electrical drive giving more power over a much wider speed range, quicker acceleration up to the selected cutting speed, and closer speed control irrespective of tool load. Hence cycle times are shorter; and a special high-speed milling head can be used for very rapid metal removal on appropriate work pieces.

Other changes are improved controls, designed to give quicker setting times, revised pushbutton layout on pendant, plastic-lined table ways, and modified lubrication system.



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SCOTTISH Machine Tool Corporation Ltd.

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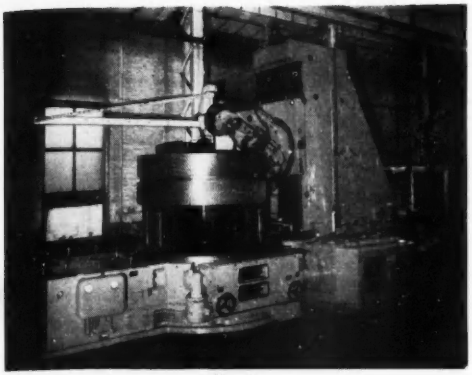

Fig. 8

errors in the master wheel and other gears in this drive. The obtaining of a continuous electrical signal of the divide-errors of the table drive as the machine is rotating is an important advancement in the design of gear-hobbing machines. In the David Brown machine, this development is taken a stage further, i.e., to the point of amplifying the error signal and utilizing it to impose fine corrections continuously through a servo-motor and correcting mechanism. As a result, the accuracy of the machine is no longer dependent on the accuracy of the master wormwheel, but is now derived from the Inductosyn, the maximum cumulative error of which is better than ± 2 sec of arc.

W. E. Sykes Ltd.

Of the comprehensive range of gear-hobbing, gear-shaving, and gear-generating machines exhibited by W. E. Sykes Ltd., of Staines, Middlesex, at least three merit special mention, these being the Model-HV14A universal hobbing machine, which is a redesigned and improved model not previously exhibited, the Model-VS4A fine-pitch gear-shaving machine with automatic cycle and hopper feed, also exhibited for the first time in Great Britain, and the Model-V10B vertical gear-generating machine, which is a completely new design with a number of novel features.

The ease with which the Model-HV14A universal hobbing machine (Fig. 9) can be set up, combined with the simplicity of its controls, makes it ideal for one-off or long production runs. Developed from the Model-HV14 machine, this new model embodies a number of substantial improvements, including a 3-hp main motor, flat and generously proportioned slideways, and a 100% increase in rapid-traverse speed. Either conventional or climb-hobbing techniques can be used, and the robust proportions of the structural castings ensure that maximum feeds and speeds can be used with absolute rigidity. A tangential-feed head, available as an accessory, can be used for hobbing wormwheels by axial feed or for producing worms with a pinion-type cutter. A positive-feed clutch trip and a safety over-run switch ensure accurate and dependable operation of the hob-carriage traverse. A wide range of additional equipment is available, including an automatic hob shift, hydraulically operated work-clamping, a high-helix-angle hob head, and a deburring attachment. The machine exhibited will be demonstrated cutting a range of 3-module spur gears.

The Model-VS4A fine-pitch gear-shaving machine for spur and helical gears will be demonstrated with a hopper feed and a fully automatic cycle. With this machine (Fig. 10), the precut blanks are delivered from the vibratory hopper to a slide placed above the work-head and tailstock, the gears being held in the slide by a gate mechanism which delivers them singly into position for shaving. With the gear located on the arbor, the pneumatically operated tailstock clamps the blank, after which the shaving cycle commences. On completion, the shaved blank is stripped from the arbor, passing out via a delivery chute. Full electrical and pneumatic interlocking is incorporated into the circuit design, and the machine is safeguarded against faulty or uncut blanks. A range of four tool speeds is provided, and the stroke is variable, as required. The machine on show will be set up for 51-tooth, 1-module helical gears of 0·275 in. face width, and will shave these components at a rate of 120 per hour. The entire cycle will be automatically controlled and will continue to repeat as long as correctly formed blanks are available from the hopper. The Model-VS4A machine will accommodate spur or helical gears of from ¼- to 4-in. diameter, with a maximum face width of 1 in. and diametral pitches ranging from 16 to 180 D.P.

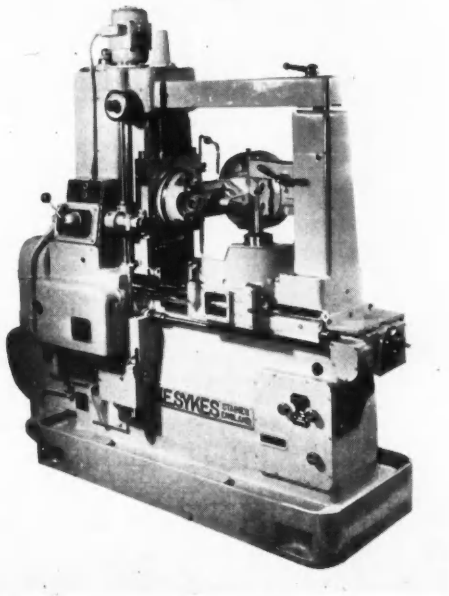

Fig. 9

The Model-V10B machine (Fig. 11) is a completely new design of vertical gear generator, combining rigidity with functional improvements. The machine is simple to operate, easy to set up, and is capable of the highest productivity for a wide range of gears and related forms. Operating on the well-known Sykes principle, the relief is applied to the cutter spindle, and the work saddle is adjustable to provide angular relief and to enable maximum radial feeds to be used. In-feed of the work is operated hydraulically and is independent of work rotation. Variable in-feeds, between 0·0005 and 0·004 inch per stroke of the cutter, can be set quickly by

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With the new GKN Spark Machine, the production of intricate shapes by electro-erosion is faster than ever; the range of finishes obtainable has been extended; and both capacity and accuracy have been increased. Installation and operating costs, however, are surprisingly low.

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Fig. 10

rotating the disc of a special hydraulic control piston and, since the hydraulic in-feed mechanism does not depend on flow-control valves, the in-feed rate remains constant, irrespective of system or ambient-temperature fluctuations. Rapid approach and withdrawal of the work takes place automatically at the commencement and end of each cycle, the final cut being taken with the saddle hydraulically loaded against a dead-stop. One-cut, two-cut, or three-cut in-feed cycles are selected by a switch, the depth of each cut being set by the adjustment of trip-rods which actuate limit-switches. The final cut,

Fig. 11

which normally takes a full 360-deg. rotation of the blank, can be modified with a plus or minus correction by adjustment of the dial of a "drop-off" indicator on one side of the machine. Cutter speeds and rotary feeds are infinitely variable through two separate Kopp infinitely variable speed units. Forward and reverse feeds are selected by switches on the control panel and are controlled by magnetic clutches.

The Model-V10B machine can be supplied in various forms, to suit particular components or special operating conditions, a major variation in classification being as standard or semi-automatic machines. The machine on exhibition will be of the semi-automatic class, in which the operator places the component on the chuck and depresses the start-button. The entire cycle then continues automatically in the following sequence:—The tailstock moves down to clamp, the workchuck expands, and the cutting cycle is initiated. Then (assuming two cycles), the saddle moves forward, first at rapid-traverse speed and then to normal feed as the work approaches the cutter. The first in-feed is stopped at the roughing depth, and the gear rotates one turn, after which the saddle in-feeds to the dead-stop and the second cut is made. When the cycle is complete, the cutter motor stops, the saddle moves back, the tailstock withdraws, and the chuck unclamps.

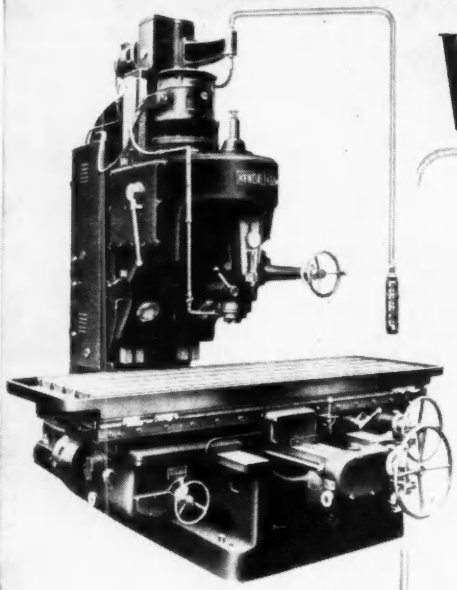
Heenan & Froude Limited

In addition to their Model S.1½ "Multiform", completely tooled and ready for demonstration purposes, Heenan & Froude Limited, of Worcester, will be showing for the first time their new S.3 "Multiform", which is the latest and largest addition to their range of automatic wire- and strip-forming machines. This machine, which has been specifically designed for the economical and high-speed production of heavier and more complex strip components, is capable of producing such components to a blank length of 12 in., a maximum width of 3 in., and up to $\frac{3}{32}$ in. thickness, at speeds ranging from 40 to 120 pieces per minute.

The production of such large and complex components necessitates increased die space, and this is adequately provided for in the design of the S.3, the die area extending to a maximum of 31 in. in length. Facilities for piercing or raising from the front or rear of the strip are incorporated. All four camshafts are inter-geared and a special flywheel is incorporated into the drive system to ensure smooth running. The flywheel can be manually or automatically divorced from the machine, so that the considerable inertia built up in the flywheel does not have to be dissipated by the rotating parts before the machine can be brought to rest. Thus, the machine can be stopped immediately (automatically, if required). As distinct from the system used in previous "Multiform" models, the S.3 drive system provides for the flywheel to be positioned to the left and rear of the machine, greatly improving access to the working parts, notably to the tooling, which can now extend practically the entire length of one side of the machine.

Special attention has been paid to the design of the feed mechanism. The connecting linkages to the reciprocating feed are in a substantially straight line from the operating crank disc, thus giving a straight through-pull from the crank to the feed and ensuring complete accuracy of feed. The stock is gripped between a pair of flat dies, one of which is mechanically operated by means of a cam. To ensure that strip up to maximum width and thickness is securely held, the grip is positively

VERTICAL MILLING ON THE CVM60



The CVM.60 combines maximum production with extreme accuracy and easy operation.

Powered by a 25 h.p. or 40 h.p. motor as required, spindle speeds range from 15 to 840 r.p.m. in eighteen steps.

Rectangular table type has working surface of 9 ft x 2 ft 9 in, and traverses 7 ft 2in x 3 ft 3 in, with a choice of four feed ranges.

Other models available with circular table or combined circular and rectangular table. Maximum height under spindle nose is 3 ft 5 in.

KENDALL & GENT LTD

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International Machine Tool Exhibition, London, 1960, Stand 27, Grand Hall, Olympia, June 25 to July 8 K 247A

applied and released by a self-contained locking mechanism which avoids sustained side thrust on the feed slide. In consequence, less effort is required to move the feed backwards and forwards. The feed slide can be positioned nearer to the ram when using short feeds and thin strip, and the provision of a grip throw-out enables the machine to cycle without feeding during tool setting. A separate grip is provided to hold the strip firmly on the return stroke of the feed side, this being operated by two adjustable cams from the front shaft. Flat-faced dies are used to grip the stock.

Sufficient room has been provided on the bed-plate for two press units, as well as the standard front cut-off. The horizontal press is designed with a standard die space of 10 in., and the entire press assembly can be adjusted along the bed-plate to obtain the best working position. A load of up to 30 tons can be obtained on each press, allowing a substantial amount of die work to be carried out. The machine can be supplied with either one or two rams and, in certain circumstances, as when the standard cut-off is not required, a third ram can be incorporated. In each case, the rams can be operated from the front or rear of the machine, thus permitting the burr on a component to be placed either externally or internally, as required, or to allow for bending or raising from front or rear. Each of the four slides is individually operated by a separate hardened and ground steel cam, each of which is capable of exerting a force of 6 tons through the slide to the component. The cams are of the pick-off type, split for easy removal, and are securely bolted to a keyed-on back-plate. A double cam track is provided on the forward stroke, allowing for a central thrust and an additional thrust on a second roller. An outer track provides positive means of returning the slides.

T. S. Harrison and Sons Ltd.

In addition to a range of Harrison lathes for industry and training, and "Union" drilling machines and grinding machines, including tool and cutter grinders, grinding and polishing machines, heavy-duty high-speed grinding machines, and tool-grinding and lapping machines, T. S. Harrison and Sons Ltd., of Heckmondwike, Yorks., will be exhibiting for the first time two new units, these being the Harrison 17-in. swing lathe and the Harrison plain horizontal milling machine.

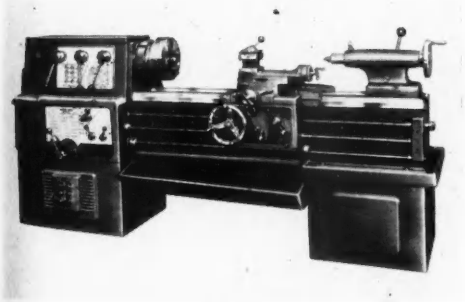

Fig. 12

The Harrison 17-in. swing lathe (Fig. 12) is an entirely new exhibit. The wide bed is cast with rear-facing apertures to allow for easy disposal of cuttings and swarf. Twelve spindle speeds, within the range between 32 and 1500 rpm, are available from a single-speed 10-hp motor, and the all-geared headstock has a three-bearing large-diameter spindle which is bored to pass a bar of 3-in. diameter. A "Matrix" reversing clutch is fitted, and the totally enclosed gearbox gives threads up to 120 per inch. The particular machine exhibited will admit 40 in. between centres, but varying bed lengths are available up to 79 in. between centres. Hydraulic built-in copying attachments can be fitted to all models of this lathe, and a complete range of attachments is available for taper-turning and milling.

Fig. 13

Primarily introduced for the smaller workshop, the Harrison plain horizontal milling machine (Fig. 13) has a 30 × 8 in. table, with either hand, power, or automatic feeds. The model exhibited has an all-geared drive which gives spindle speeds from 67 to 1500 rpm. However, a vertical head, with speeds up to 3000 rpm, is also available for this machine.

Drummond-Asquith Limited

An extremely wide range of equipment will be featured by Drummond-Asquith Limited, of Birmingham 2, including Asquith ram-type milling and boring machines, girder end-facing machines, and boring and drilling machines, as well as Drummond gear-shaping machines and lathes, and a Drummond automated gear line, comprising lathes, and gear-hobbing and shaping machines. In addition, exhibits will include Warner & Swasey lathes, a Blackburn horizontal-spindle copy-milling machine, Forst keyseating machines and vertical broaching machines, Krause 6-spindle fine-boring machines, Nassovia automatics and automatic die-sinking machines, Manurhin automatic lathes, Ohler hydraulic sawing machines and saw-blade sharpening machines, Waldrich hydraulic double-column planing machines, Lidkoping centreless grinding machines, and Wolpert hardness-testing machines and combined Rockwell and Vickers testing machines.

Other Drummond-Asquith exhibits include Staffa

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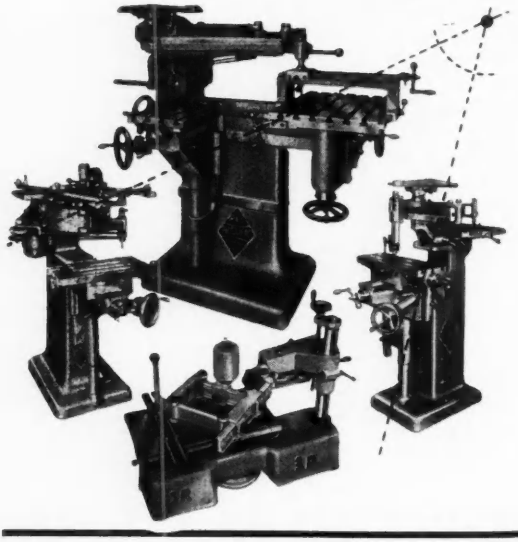


Precision engraving and die-sinking machi

Accessories supplied

THREE-DIMENSIONAL MODELS

PK.1 **PK.2** **PK.3** **SR.3D bench**	For milling and cutting dies in steel, m punches, chills, moulds for plastic ma rubber, glass, etc.

TWO-DIMENSIONAL MODELS

P.1	**Ratio 1 : 1 – 1 : 50**	For engraving meta
P.2	**,, 1 : 1 – 1 : 25**	other materials, pl
P.3	**,, 1 : 1 – 1 : 10**	number plates,
SR.2D bench	**,, 1 : 2 – 1 : 6**	panels for elec
SD ,,	**,, 1 : 2 – 1 : 4**	switchboards, etc.

Grinders for centre punches, dividing equipment, t
tables, indexing fixtures, etc.
Hardness Testers.

FORM-GRINDING MACHINE "BRUCO"

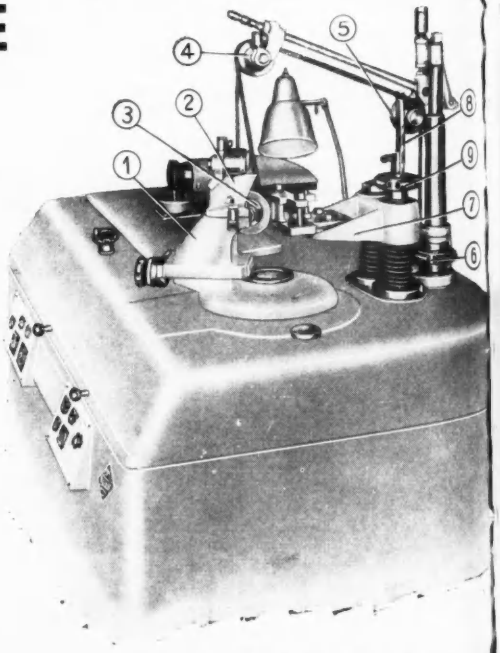
With fixed ratio between template and workpiece of 5 : 1.

Working area of wheel $2\frac{3}{8}'' \times \frac{5}{8}''$.

Vertical stroke 4". Effective stroke 3".

Details of transmission unit and work table:—

(1) Wheel-head. (2) Wheel-head cover. (3) Grinding-wheel spindle. (4) Pulley. (5) Pulley with circular-section belt. (6) Handwheel for belt tension. (7) Hydraulically operated work-table. (8 & 9) Table adjustment and locking handwheel.



bending machines, "PeTeWe" projection form grinding machines, "Hi-ton" presses, Swift lathes, Swift-Summerskill open-side planing machines, and a range of Dawson cleaning machines, including the Dawson fully automatic in-line cylinder-block washing machine. This patented machine, which is made by Dawson Bros. Ltd., of Gomersal, near Leeds, provides high-precision cleaning to remove all cast-iron swarf and cutting oils from cylinder blocks prior to assembly of engines, and is capable of handling 80 blocks per hour.

A particularly spectacular exhibit will be an Asquith 14-station in-line transfer machine for operation on Austin-Seven cylinder blocks. This machine (Fig. 14), which is approximately 65 ft in length, provides, among other operations, for semi-finish and finish boring of the crankshaft and camshaft bores, facing each side of the central crankshaft bearing, and reaming the crankshaft and camshaft bores. At station No. 8, a split liner bush is aligned automatically and is pressed into one end of the camshaft bore, this bush being fine-bored in position at the next station. After this operation, the block is turned through 90 deg., and three successive stations provide for a series of operations on the distributor bore.

An air-operated travelling carriage picks up a cylinder block from the roller track at the entry end of the machine, transports it to the transfer bar, and lowers it into engagement with two locators which enter the centre pair of cylinder bores. The transfer bar is indexed to bring the block to station No. 2. The bridge-type fixture used is typical of those provided on the machine, with the exception of station No. 5, and the locating and clamping arrangements are common to all stations. Horizontal guide rails on either side of the transfer bar are interrupted to receive two vertically moving jacks, which are raised and lowered hydraulically. When the transfer bar is moving a cylinder block into position, the jacks are level with the guide rails. After the transfer bar has completed its movement, the jacks raise the cylinder block from the locators on the transfer bar and thrust it against the underside of the bridge fixture. The final alignment is determined by two vertical plungers which are advanced by two vertical oil cylinders on top of the bridge fixture. These plungers enter ½-in. diameter reamed holes in the sump face of the block. Swarf is carried from the machine by an endless-chain conveyor. The main control console, from which all movements of the machine can be initiated, incorporates a simple fault-finding arrangement of lights which indicate "heads back", "jacks up", "jacks down", "locators in", and "locators out". Individual electrical controls are also incorporated at each station.

The Churchill Machine Tool Co. Limited

Exhibits from The Churchill Machine Tool Co. Ltd., of Broadheath, comprise a Model BW 10 × 20 in. automatic-gauging plain grinding machine with automatic wheel-truing and compensation, a Model HBM automatic-sizing internal-grinding machine with automatic facing, a Model EC centreless grinding machine, with automatic hopper feed and automatic gauging control, a Model AW 6 × 18 in. plain grinding machine with diminishing feed and power wheel-truing device, and a Model TWA 32 × 192 in. heavy-duty roll-grinding machine with electronic wheel feed.

This heavy-duty roll-grinding machine (Fig. 15), which is one of a range recently developed in collaboration with roll-makers and mill engineers in the steel industry, is of particular interest. In these machines, the beds are in two sections, one of which is for the traversing wheel-head carriage, which carries the grinding wheel, wheel-feed mechanism, and traverse gearbox, with electrical controls, tachometer, etc. The other section is constructed to provide maximum rigidity for supporting and rotating even the heaviest rolls, the two sections being bolted together along the entire length. A 36-in. diameter grinding wheel is fitted as standard, and the wheel-head, which is designed for maximum bearing rigidity, is provided with a large-diameter spindle driven by a 40-hp variable-speed motor. The feed wheel is graduated to read 0·000125 in. Rapid power traverse is provided, with a push-button control.

The machine is fitted with the Churchill patented automatic electronic feed, by means of which the maximum use is made of the power available at the grinding wheel—a feature that has contributed considerably to high metal-removal rate. This is an exclusive feature and, apart from being a valuable time saver, requires less operating skill to keep the grinding wheel cutting at a steady rate, the power absorbed by the grinding wheel being kept virtually constant. In operation, the wheel feed is applied by hand until the load has been picked up, and the wheel is traversed along the roll face, the mechanical loads on the grinding-wheel motor falling because of the material removed, and correspond-

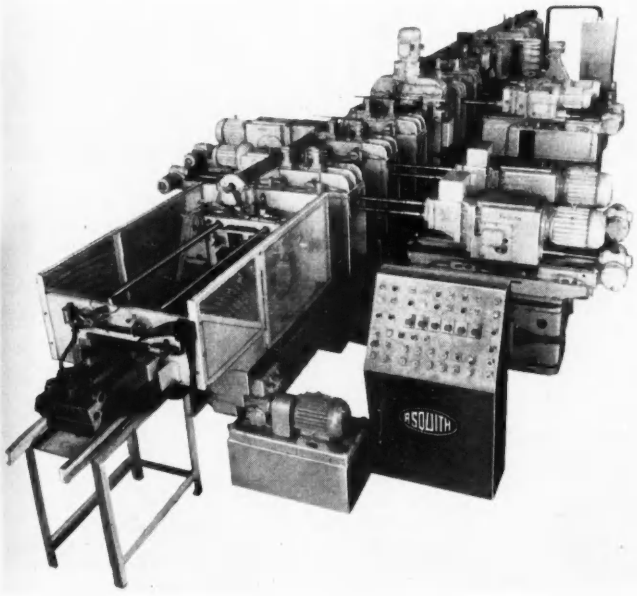
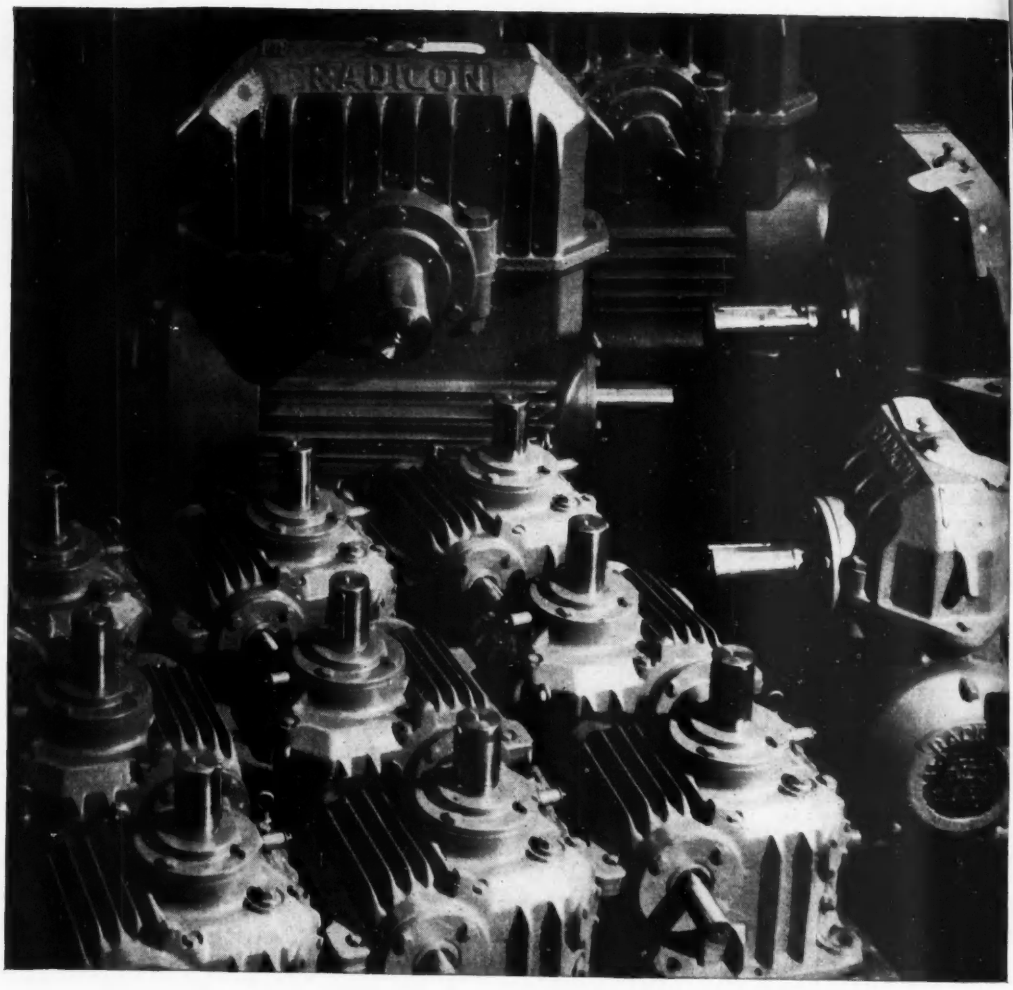


Fig. 14



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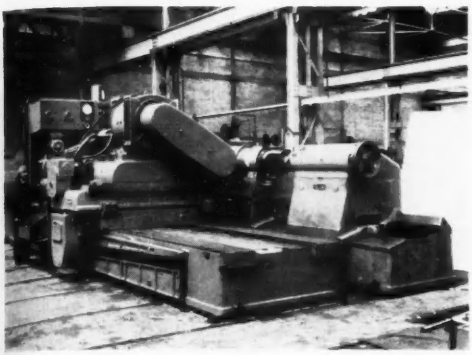

Fig. 15

ing reductions in the motor-armature current then taking place. The automatic feed mechanism is designed to ensure that a feed is applied immediately after a fall in current takes place. The operator can set the load-regulator to any value of load current within the capacity of the grinding-wheel motor. This automatic feed is ideal for finish-grinding, as the feed regulator can be adjusted to a low value and, as the finish is built up, it can be reduced in stages down to the lowest setting. The process of finishing becomes automatic, the amounts of feed being smaller than those which can possibly be obtained by hand.

H. W. Kearns & Co. Limited

In addition to a range of surfacing and boring machines, including the Kearns patent No. 3 W.B. electronic universal surfacing, boring, milling, drilling, tapping, and screwcutting machine, fitted with the A.E.I. two-dimensional automatic co-ordinate setting system, H. W. Kearns & Co. Limited, of Broadheath, will be exhibiting for the first time their entirely new Model-451P "Optimetric" horizontal surfacing, boring, milling, drilling, and tapping machine fitted with a patented hydraulic tool-clamping and release system.

Equally suitable for the tool-room or for general workshop use, this machine (Fig. 16) incorporates several exclusive and patented features, including a main bed of cellular construction, with a special channel in the centre, directly under the centre-line of the travelling spindle. The channel houses the longitudinal screw and shaft, together with their associated mechanisms, and, as the channel is filled with lubricant, these parts, including the centre bed way, are submerged in an oil bath. The centre-guide on the saddle slides in this special bed channel; at the same time, the outer ends of the saddle are carried on large rollers which rotate on anti-friction bearings and are supported by the outer bed ways.

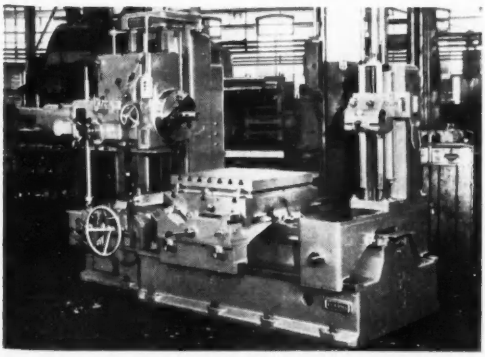

Fig. 16

A totally enclosed, foot-mounted 7½-hp motor is bolted at the back of the main bed, where any heat or vibration generated has a minimum effect on the machine. The drive from this motor is through plastic belting to a 9-speed gearbox of special design. Three gear changes in the spindle slide, combined with the nine speeds of the main-drive gearbox, give a total of 27 speeds. An outstanding feature of the machine is its versatility, as a result of the combination of the travelling spindle with a built-in automatic facing chuck. The feed mechanism to the facing slide is also patented and consists of only three simple components, i.e., a large-diameter concentrically-mounted worm which drives twin spiral gears working directly into two racks attached to the facing slide.

A new and important feature is the hydraulic tool-release and clamping system for the main spindle, this simple mechanism being operated by a rotary switch fitted in the main control pendant attached to the machine. In order to ensure accurate and constant effort when holding the non-stick mandrels into the spindle nose, the central draw-bar is pulled into position by a powerful spring housed in the end of the main spindle, a bayonet catch enabling the mandrel to be withdrawn easily and quickly. The spring is overcome by applying a hydraulic pressure to a cylinder attached to the end of the spindle. This simple mechanism is designed to fail-safe and enables tool-changing to be carried out with great speed and a very high degree of accuracy.

The patented "Optimetric" system is provided to the vertical adjustment of the spindle slide and boring stay bearing and transverse movement of the table. This projection system enables settings to be made to 0·001 in. to a limit of error of ±0·00025 in. To assist the operator in setting, all scale mounts are adjustable in their housings.

B.P.S. Machinery & Spares Co. Ltd.

Exhibits from the B.P.S. Machinery & Spares Co. Ltd., of London, S.W.7, will include a Schaffner universal cylindrical grinder, a Schaffner universal mill, a Witzig & Frank drum-type automatic, and a Müller light radial drill. In addition, a range of Pittler lathes will be featured, including the "Piropa" high-speed turret lathe, the front-loading "Pifat" automatic, which is a single-spindle version of the double-spindle "Pidofat", and the "Piropta" turret finishing lathe, which is made under licence from Zeiss and has been specially developed for the optical industry.

An exhibit of special interest will undoubtedly be a special-purpose Binns & Berry lathe carrying the Burgsmüller thread-whirling attachment, in which a series of single-point tools, mounted in a heavy ring, rotates around the work at high speed, taking a rapid succession of small cuts. This ring is inclined at the necessary helix angle and is fed along the lathe bed in the usual way, thus cutting the required thread. The "Whirlmatic" machine exhibited (Fig. 17) has been developed as the result of close co-operation between Burgsmüller, the B.P.S. Machinery & Spares Co. Ltd., and Binns & Berry Bros. (Halifax) Ltd., and has several features of interest, including automatic cycling to feed

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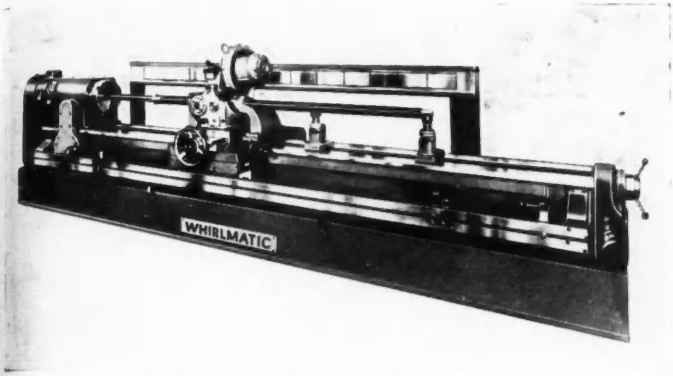


Fig. 17

the tools to full depth, automatic traverse, and high-speed return of the cutting head. A large-diameter central leadscrew ensures maximum accuracy and smooth movement of the saddle. In addition, the machine features a special mechanism in the form of a pitch corrector. This mechanism enables the measured errors in a test screw cut on the machine to be corrected automatically on a second pass, or on the next similar screw being cut. This correction is achieved by a light-sensitive cell reading the errors previously recorded, feeding back the necessary correction to the floating leadscrew, and moving it backwards or forwards, as required, to correct the error.

Also to be shown on this machine will be the new Burgsmüller high-speed spline and keyway slotting head, which is capable of cutting keyways at speeds of the order of 40 inches per minute.

Landis Lund Limited

Among other machines, including fine-boring machines, cylindrical grinding machines, and automatic bearing inner-race and ring grinding machines, Landis Lund Limited, of Cross Hills, Keighley, Yorks., will be showing the 5-in. Type-DH automatic camshaft form grinding machine and the 16-in. Type-DH automatic crankpin grinding machine, both these machines being of American design.

The 5-in. Type-DH automatic camshaft form grinding machine (Fig. 18), which will swing work of 5½ in. in diameter and will take 26 in. between centres, is of heavy construction, with an extra-heavy wheel-base carrying the grinding-wheel spindle in Landis Tool Company "Microsphere" bearings. The work drive is 100% Vee-belt, and automatic slow-down of work speed for finishing, and automatic stopping of the head for convenient loading position are exclusive production features. Up to 0·120 in. on stock can be removed from work diameters, and tapered cams can be ground without difficulty. The maximum grinding-wheel width is 1¾ in., and the wheel is dressed from a hydraulically operated dresser mounted on the wheel-base. Dressing is automatic on completion of the grinding of each camshaft, and compensation is made automatically to the wheel feed. The grinding cycle is fully automatic and includes rapid approach of the grinding wheel, grinding, rapid wheel withdrawal, and indexing for each cam profile to be ground. The machine to be exhibited will be demonstrated grinding a four-cylinder automobile camshaft.

The 16-in. Type-DH automatic crankpin grinding machine (Fig. 19), which has a capacity of 16 in. swing by 32 in. length, has been designed specifically for the efficient grinding of all types of crankshafts on a rapid-production basis. The machine grinds the diameter and sidewalls of four crankpins, stock removal being from 0·03 to 0·04 in. from each diameter and from 0·010 to 0·015 in. from the sidewalls, with a production rate of 13 complete shafts per hour. In addition to "Microsphere" grinding-wheel-spindle bearings, this hydraulically operated machine, which will be demonstrated grinding a four-cylinder automobile crankshaft, has telescopic slide-way covers, automatic application of work rest, automatic sizing, and conveniently located controls.

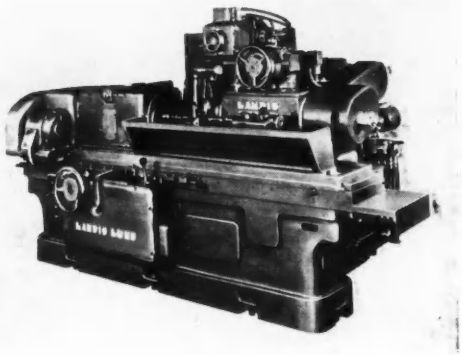


Fig. 18

The grinding-wheel feed is arranged for a rapid approach of the wheel until it is in the cheek-grinding position, after which a reduced rate of feed is engaged for grinding the cheeks, with still further reduced rates of feeds when grinding the crankpin diameters. Final sizing is effected by a Landis Tool Company "Microfeed" unit operating in conjunction with automatic sizing by means of a pneumatic electric contact gauge. The

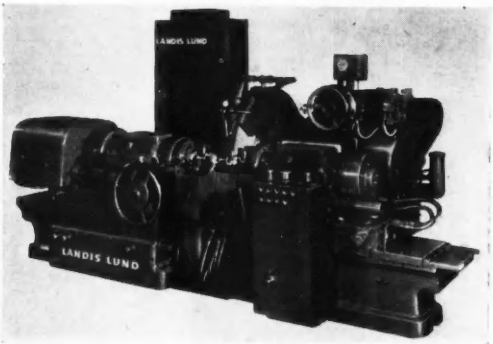
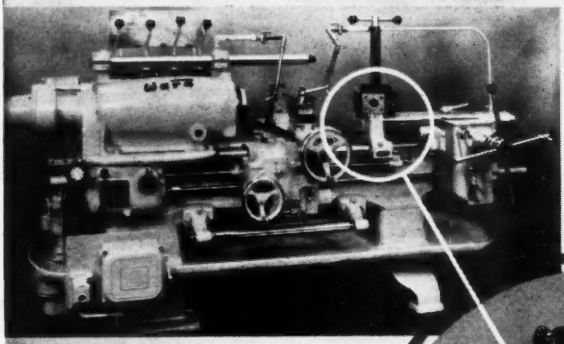


Fig. 19

Ward DOUBLE-SLIDE CAPSTAN LATHES



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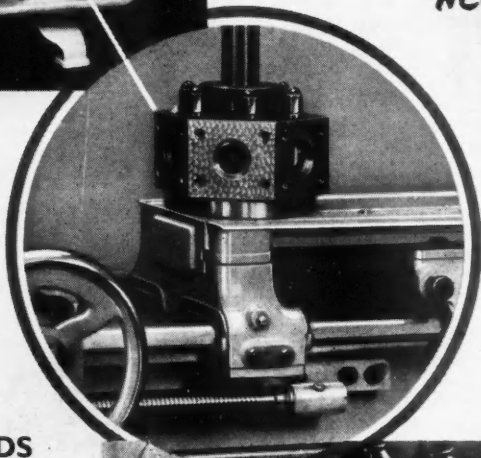

Throughout the whole of its forward movement, the hexagonal turret is supported underneath by a sliding bridge which is in direct contact with the bed on all its working surfaces. This ensures correct alignment at all times, whatever weight of tools the turret carries.

The New DOUBLE-SLIDE allows heavier work with higher rates of metal removal

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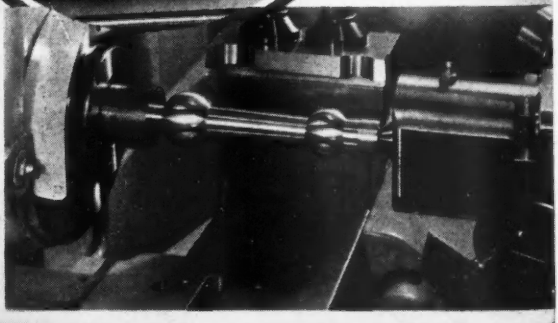
with oversize Spindle	1½in	2in	2½in



Ball Handle 6⅜in. long form-turned from the cross-slide in one cut on a No. 3DS.

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diameter of the grinding wheel is 36 in., and wheel dressing is carried out by the recently introduced Landis Tool Company "True-Form" wheel-dressing attachment, which is mounted on the grinding headstock of the machine and which, in addition to dressing the periphery of the wheel, also dresses the full 90-deg. radii on each corner.

Henry Broadbent Ltd.

In addition to a 10-ft vertical boring and turning mill, a 25-in. swing surfacing and boring lathe, and a 36-in. swing centre lathe with a bed length of 18 ft 3 in., admitting 10 ft between centres and with a maximum swing of 56 in. by 20 in. in front of the faceplate, Henry Broadbent Ltd., of Sowerby Bridge, Yorks., a member of the Kerry Group Manufacturing Division, will be exhibiting an 18-in. swing sliding, surfacing, and screw-cutting lathe, which has been newly designed to meet with modern requirements for high metal-removal rates.

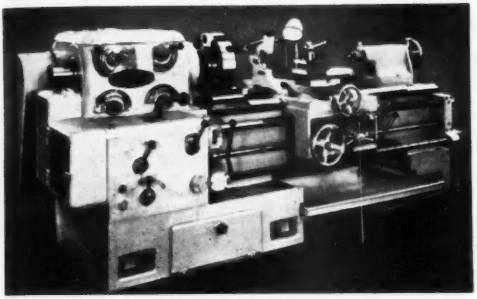


Fig. 20

In this machine (Fig. 20), which is of extremely sturdy construction, the headstock has all shafts and the spindle mounted on ball or taper roller bearings. The spindle has an extremely rigid mounting consisting of two taper roller bearings at the front and roller bearings at the rear, with a further bearing in the centre rib. All gears are of nickel-chrome steel, and are shaved for silent running. The diagonally ribbed bed has inserted shears. Hardened and ground beds can also be supplied with a detachable gap piece; in this case, the bed shears are integral and have chilled surfaces. The totally enclosed feed-box covers all English and American threads and, with a few change-wheels supplied, is capable of cutting diametral pitch, circular pitch, metric, and module. The machine can also be offered with the Hepworth copying attachment built into the machine, and is also manufactured with a swing of 22 in. over the bed. A full range of accessories and equipment can be supplied.

Qualters & Smith Bros. Ltd.

The latest additions to the well-known "Sawmaster" range of saws manufactured by Qualters & Smith Bros. Ltd., of Barnsley, a member of the Kerry Group Manufacturing Division, are the "Sawmaster" bandsaws, types 10B "Autocut" and 10B "Standard". The type 10B "Autocut" bandsaw to be exhibited (Fig. 21) is fully automatic and has a maximum capacity of 9-in. diameter and up to 12 in. wide by 6 in. deep.

The saw-blade, 150 in. in length, 1 in. in width, and $\frac{3}{32}$ in. in thickness, passes over two 17-in. diameter wheels, one of which is driven by a 1½-hp motor through an infinitely variable cone friction drive. The blade guides are supported on cylindrical bars, adjustable

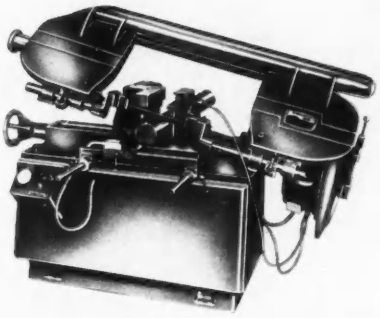


Fig. 21

lengthwise in sleeves attached to the lower edge of the saw frame. Coolant equipment is provided, coolant being directed onto the blades at the guide-posts through a flexible pipe and tap. The coolant tank is located behind a hinged door at the rear of the bed.

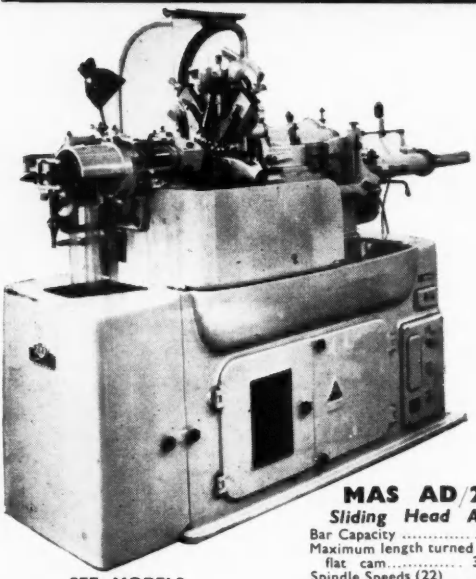
A control panel is fitted at the front of the machine and contains push-buttons for starting and stopping the blade and for raising the saw frame. Limit switches are mounted at various positions on the machine to control the automatic cutting cycle. A switch is provided on the control panel for converting the automatic cycle into a standard cycle, if required. For fine adjustment of the hydraulic dashpot cylinder controlling the down feed of the saw frame, a control dial is fitted to the front of the machine. At the beginning of each cutting cycle, the bar is fed through a vice of the "draw-in" type by rollers driven by a ½-hp motor and, when it makes contact with an adjustable end-stop, a limit-switch is operated to stop the rollers. The saw frame then descends to perform the cutting operation. When cutting has been completed, the saw frame is raised and is caused to dwell in the upper position, while the bar stock is again fed lengthwise. An electrical counting device can be fitted.

B. & S. Massey Ltd.

The range of hammers to be exhibited by B. & S. Massey Ltd., of Openshaw, Manchester, includes a No. 3 double-acting hydraulic hammer, a 7-cwt "Clear-Space" pneumatic power hammer, and a 10-cwt Massey "Marathon" electrically driven drop hammer, the smallest in a range up to 40 cwt. This type of hammer now incorporates the recently developed "Aeromatic" gear which enables the operator to control the hammer by a single pedal. This pedal is extremely light in action and provides light or heavy blows of predetermined stroke. Alternatively, when required, the "Aeromatic" gear can be disconnected and the hammer controlled by hand.

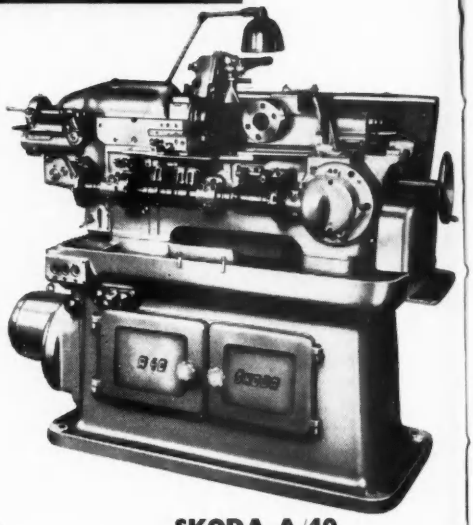
The presses exhibited will include a 1000-ton high-speed forging press, but special interest attaches to the 100-ton "Wide-Ram" trimming and setting press, which is the latest addition to the range of Massey forge and drop-forging plant. This press (Fig. 22) is the smallest in a range from 100 to 1000 tons, with table working areas from 46 × 30 in. up to 84 × 50 in. Each press is provided with four one-piece cast-steel pitmans, thus ensuring maximum resistance to tilting of the ram. All bearings are of generous proportions, and the clutch is of the direct, air-operated friction type. The lubrication unit is automatically interlocked with the main press drive, so that, when the press is in operation, adequate

High Speed AUTOMATIC LATHES



MAS AD/25
Sliding Head Auto.

Bar Capacity ..... 1"
Maximum length turned using flat cam..... 3 15/16"
Spindle Speeds (22) 305 to 3920 r.p.m.



SKODA A/40

Bar Capacity ..... 1 13/16"
Maximum Turning Length ..... 3 11/32"
Spindle Speeds (16) ..... 300 to 2000 r.p.m.
Spindle speeds screwcutting ... 75 to 510 r.p.m.

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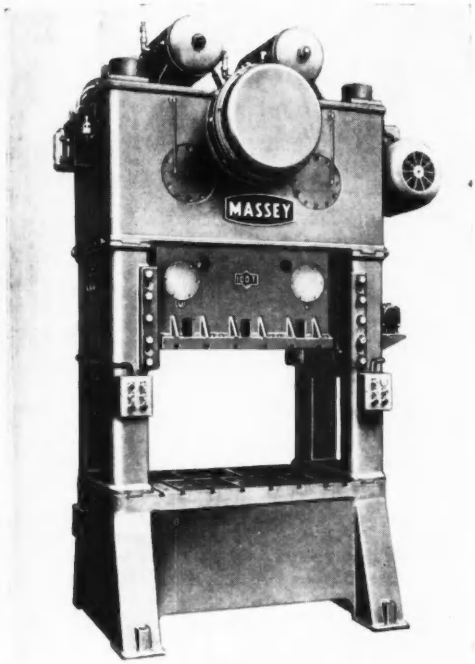

Fig. 22

lubrication is provided for all moving parts. Alloy-steel double-helical gears provide the transmission elements. The frame, comprising bed-plate, uprights, and crown, is of box-type welded-steel construction, the whole frame structure being held together by four large-diameter bolts shrunk into position.

Wild-Barfield Electric Furnaces Ltd.

Equipment to be exhibited by Wild-Barfield Electric Furnaces Ltd., of Watford, Herts., will be representative of the Resistance-Furnace, Induction-Heating, and Vacuum Divisions of the company. Thus, high-frequency induction-heating equipment will feature a new Wild-Barfield AHF 2·5-kW generator, with an intermittent rating up to 3 kW, incorporating full-range power control. In addition, a standard 25-kW set will be exhibited in conjunction with a new progressive vertical and rotary hardening machine, designed to have a very wide range of application.

An interesting demonstration will be the manufacture of low-pressure die-castings, by arrangement with Alumasc Limited, of Burton Latimer, Northants., who are supplying the necessary material. The process will be demonstrated using a Wild-Barfield mains-frequency induction-heated aluminium holding furnace of 300-lb capacity, replenished from a mains-frequency induction-heated bale-out furnace of similar capacity.

The keynote of the furnace exhibit will be the scientific control of an active process atmosphere and, to demonstrate this, two types of sealed quench furnace will be exhibited, operating in conjunction with an endothermic gas generator. Complete control of atmosphere conditions to suit changes in material and/or application is achieved in the larger furnace by fully automatic dew-point control on both the gas generator and the furnace, which will be a full-scale production "Ace" type, complete with full ancillary equipment, the working dimensions of the furnace chamber being 20 × 16 × 10 in. The smaller furnace will be of the hand-operated slipper type, for the clean hardening, etc., of small components, such as parts of small ball bearings. The G.W.B. endothermic generator will operate on bottled propane.

Edgar Allen & Co. Limited

A comprehensive display of engineers' cutting tools, form tools, deposit-welded tools, die steels, alloy-tipped hot saws, and examples of progress in powder metallurgy will be exhibited by Edgar Allen & Co. Limited, of Sheffield 9, including the range of "Stag Major" high-speed-steel butt-welded tools, hardened and ready for immediate use, "Athyweld" humped-back deposit-welded parting tools, designed to avoid recurring tool breakage, and Allenite tungsten carbide "Plowrake" tools, which can plane high-tensile-steel castings, die blocks, etc. at speeds of 80 to 100 fpm with an approximate depth of cut of $\frac{3}{4}$ in. and a feed of $\frac{1}{32}$ in. per stroke.

Hard-facing materials of various characteristics and analyses, up to 85% tungsten carbide alloys, will be shown applied to earth- and rock-processing equipment. A method of depositing hard-wearing faces will also be exhibited for the first time. The material, deposited on sample components by a metal-spraying process, is not mechanically bonded but is fuse-welded to the parent metal, its function being to provide a relatively thin but high-abrasion-resistant surface.

Finally, an 18 × 36 in. fine-pole magnetic chuck with push-button automatic chuck controller will be introduced. This chuck is a product of J. H. Humphreys & Sons Ltd., of Oldham, a subsidiary company of Edgar Allen & Co. Limited, and will be shown demonstrating the operating cycle of the demagnetizer controller.

Edgar Vaughan & Co., Ltd.

The oil service for machine-tool exhibitions, offered by Edgar Vaughan & Co., Ltd., of Birmingham 4, at every machine-tool exhibition since 1912, will be operating this year on a greatly increased scale. To provide for the large quantities of metal-cutting oils, lubricants, and hydraulic oils required, a temporary oil store, with handling and transporting equipment, will be installed and, for the convenience of exhibitors using the oil service, a separate oil-service office will be installed on the stand itself.

Samples of a few newly developed products of the company are to be exhibited, including a range of quenching media which provide cooling rates varying from a speed slightly lower than that of water to half the speed of conventional quenching oil. In addition, exhibits will include a light-coloured neat cutting oil which has given remarkable efficiency in machining operations on the most difficult materials, a water-soluble, oil-free grinding fluid, which affords complete corrosion protection to both ferrous and non-ferrous metals, a dry-film drawing compound giving heavy-duty drawing efficiency combined with protection of stock and components during storage, and a range of hydraulic/lubricating oils which provide trouble-free hydraulic service and complete elimination of stick-slip. Other products include fire-resistant hydraulic fluids and a rust preventative which incorporates water repellency, fingerprint neutralization, and long-term protection, combined with fluidity and ease of application.

(Other exhibits will be reviewed next month)

Lubrication Plus Protection

Mobilux Grease is a lithium base lubricant of excellent structural stability and purity. It is a new, general-purpose grease superseding conventional greases. It provides effective lubrication for the majority of grease applications over a temperature range from minus 20°F to 250°F. It is exceptionally resistant to water washing and contains special additives to prevent rust formation. Both in the laboratory and in the field Mobilux Grease has proved its outstanding efficiency as a lubricant and protector.

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Blending Unit for Heavy Oils at the Mobiloil Ocean Terminal

The problem of mixing two streams of liquid together in certain volumetric proportions is not new and has in the past been solved in various ways, most of which, however, use very complicated and expensive pneumatic or electronic controlling mechanisms. A few years ago, the Fisher Governor Co., of Marshalltown, Iowa, developed a unit using the principle of maintaining a constant pressure drop across two orifices, the areas of which could be varied to obtain any desired ratio of blend. In this way, the normal complexity of instrumentation was eliminated, and a self-contained unit of the utmost simplicity was produced, with an adequate accuracy for most applications involving such fluids as low-viscosity oil products.

To meet the demands of the heavy-oil distribution companies, this unit was later modified in England by the Fisher Governor Co. Ltd., of Rochester, and was further developed to enable it to handle high-viscosity oils, up to 5000-sec Redwood No. 1, the object being to blend together, in a predetermined volumetric or mass ratio, a high-viscosity fuel oil with one of lower viscosity to obtain an oil of an intermediate viscosity. This unit employs the principle of parallel metering of the two oils and arranges that the pressure losses across the two metering areas are kept equal. Since the viscosity of the heavy fuel changes rapidly with temperature, this component is metered through a fixed orifice of special design, i.e., the edge contour is such that the discharge coefficient remains reasonably constant over wide fluctuations in viscosity. The light-oil component is metered through a variable orifice in the form of a metering valve of the sleeve-and-piston type, as illustrated in Fig. 1, which is a detail of a standard metering valve, showing the handwheel counter and piston-type inner valve.

The pressure-balancing unit consists of two pressure-regulating valves actuated by a common diaphragm. Pressure tappings are taken just upstream of the fixed orifice and meter valve respectively, and are piped to either side of the diaphragm. The inequality in pressure at these two metering points causes the common valve-stem assembly and inner valves to move, thus changing the pressure losses of the two streams through the unit, raising the lower and reducing the higher until equal pressure is obtained. It should be noted that this system of balancing removes the necessity for accurate pump pressure settings, and is equally effective with rotary or reciprocating types of pump.

The pressure upstream of the two metering areas must be equal and, since they have a common downstream pressure at the junction of the two streams, the pressure losses across these areas are kept equal. The blend ratio and the ultimate blend viscosity are therefore obtained by direct proportion of the areas across the two metering devices. As one is fixed, the blend ratio can be written as a function of the metering-valve travel. A turbulence vane is fitted at the outlet of the unit to ensure homogeneity of the mixture.

The particular requirements of the Mobil Oil Co. Ltd. for their ocean terminal at Ellesmere Port are generally more difficult, in that a relatively high degree of accuracy is required, together with simplicity of construction and low maintenance. As, however, the Fisher in-line blending unit met the latter requirement, the Mobil Oil Co. proposed that a unit of the type described could be used in conjunction with a viscosity controller which, although adding a certain amount of complexity, would improve performance and would at the same time simplify the operation of the unit, in that individual calibration is not required. The scheme finally adopted was that of using a specially designed Smith viscosity controller. By means of an electrical signal, this controller, which was described in detail in our issue for May 1960, trims the setting of the metering valve in such a way that a viscosity error causes the metering valve to open or close as required.

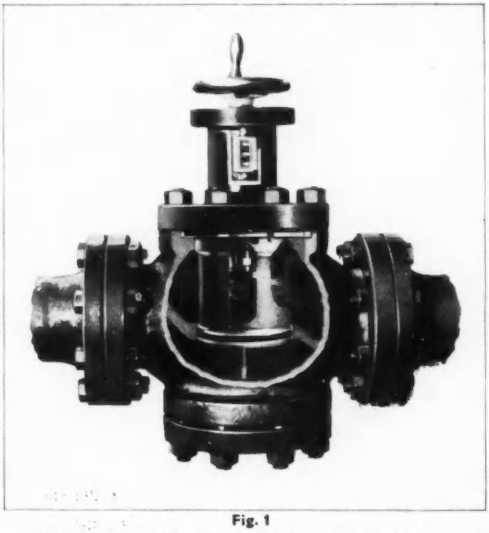
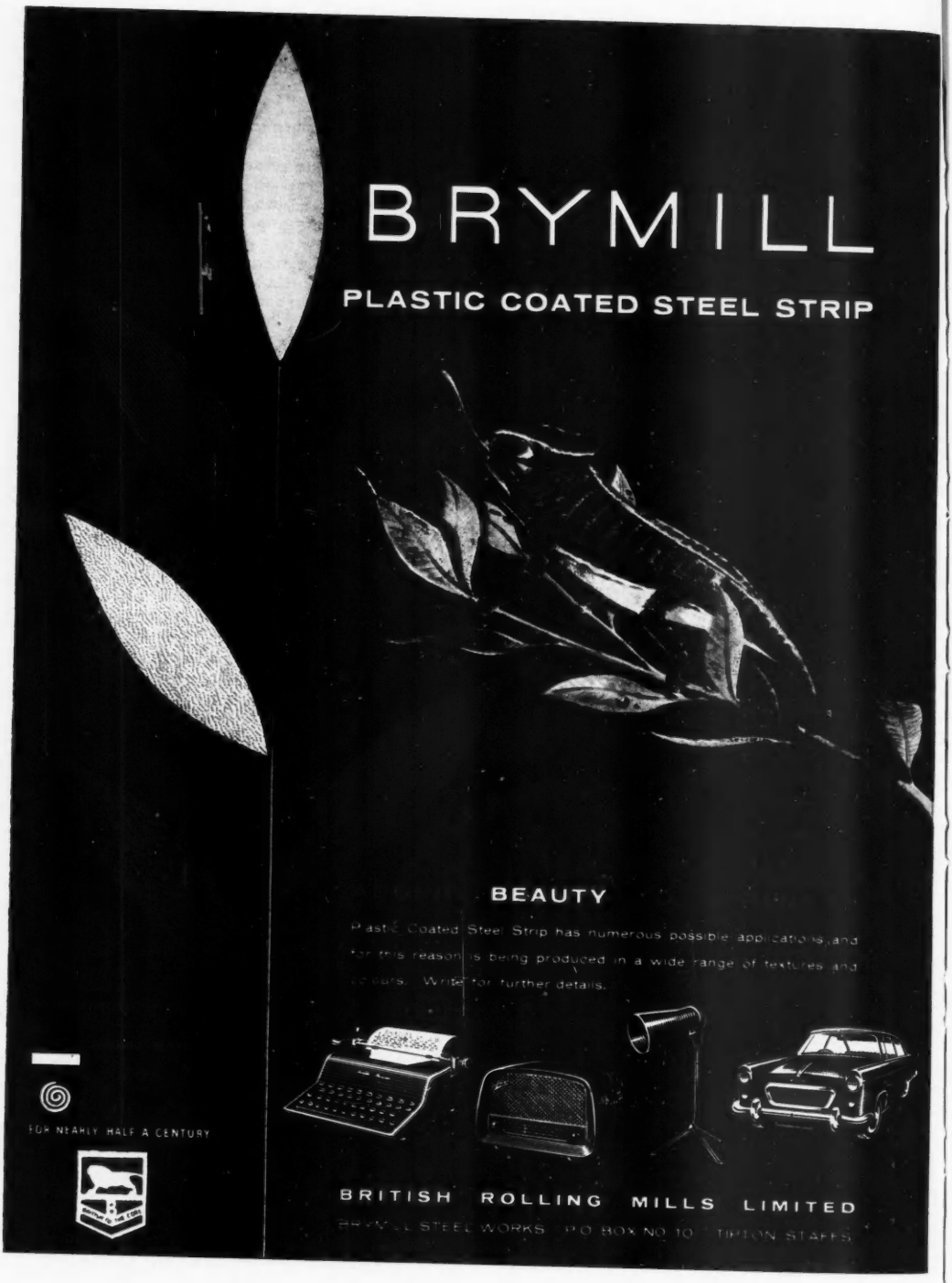


Fig. 1

With previous blending units it was found that, with the normal turbulence vane fitted just after the junction of the two streams, a perfect mix was obtained a few yards downstream. This was adequate for bunkering purposes, but the use of a viscosity controller required that a perfect mix must be obtained in the shortest possible time if the system time-lag was to be kept reasonably short. Experiments were carried out using various devices for increasing turbulence, but those effective at low flow rates caused excessive pressure drop at high flow rates. An electrically driven mechanical mixer was eventually chosen to overcome this problem.

In the system used at the Mobiloil ocean terminal, the two components coming from the pumps enter the blending unit, where the pressure of each component is automatically equalized by self-operated pressure-balancing valves. The high-viscosity oil then passes through a fixed orifice, whilst the low-viscosity oil passes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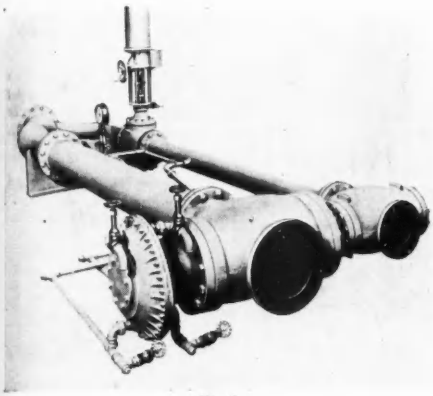


Fig. 2

through the metering valve, which proportions the flow as required. A pressure-difference sensing switch is fitted across the fixed orifice to switch on the second black-oil pump when the flow reaches the maximum value of the first pump. When the two streams are in more or less the correct proportions, they are joined together and passed through the mixer. A sample is then extracted for comparison with a "standard" by the Smith viscosity controller, which transmits a signal in accordance with the deviation of the sample, and the metering valve is reset, if necessary. The blended product is then piped straight to the loading arms, which are fitted with pressure switches to start the pump automatically when required. A view of the special type of blending unit for this ocean terminal is given in Fig. 2, which shows the inlet valves and balancing diaphragm.

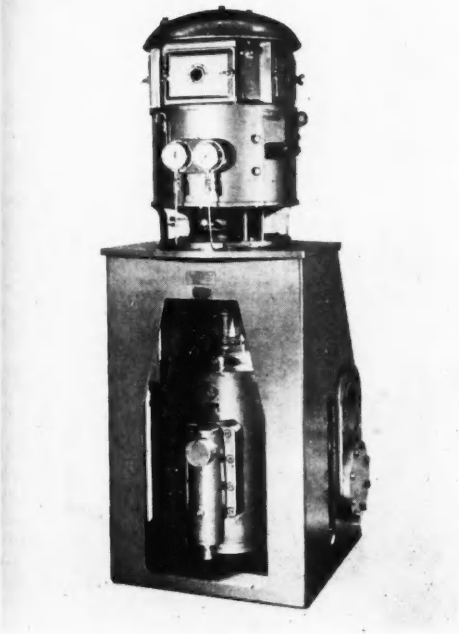


Fig. 3

To handle the heavy fuel oil, eight type SVF 3800 L3 Hamworthy vertical positive-displacement electrically driven screw-pumps are mounted in line on a concrete base. Arranged in pairs, they deliver oil from the storage tanks through the blending units to the loading stands. Each pump (Fig. 3) is designed to handle 530 gpm of heavy oil with a viscosity of 2250-sec Redwood No. 1 at 120° F at a working pressure of 110 psi.

Miniature Electromagnetic Clutch and Clutch Coupling

A miniature electromagnetic unit, the S.F.100, only $1\frac{1}{8}$ in. in diameter, has been added to their Warner range by Westool Ltd., of St. Helen's Auckland, Co. Durham, and is designed to transmit a maximum static torque of 2 lb-in. Rated at only 6 W and with a response time of a few milliseconds, the new miniature clutch (or clutch coupling), which can achieve a maximum speed of 15,000 rpm, is particularly suitable for use in control mechanisms on light instrument drives, computers, and servo-mechanisms.

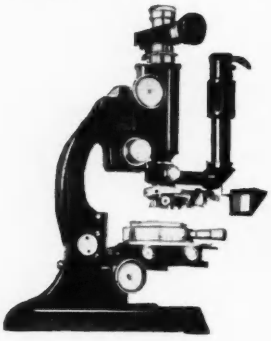
The unit consists of one stationary part and two rotating parts. The stationary member is the field which contains the coil and, when this is energized, flux flows from the field to the rotor, which attracts the armature, allowing the driving member to be coupled to the driven member. The armature is mounted on a splined hub, the hub being attached to either the driving or driven shaft, thus allowing the armature to move axially for automatic compensation of wear and effective release when the clutch is de-energized.

Stator Winder for Small Electric Motors

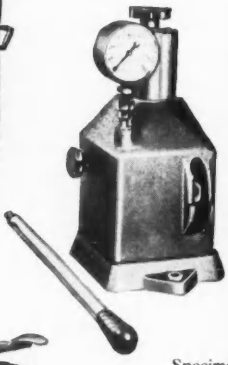
Originally designed and manufactured for their own use by the British Vacuum Cleaning Co. Ltd., of Leatherhead. Surrey, a stator-winding machine for small multi-slot stators is now available generally from the Catmur Machine Tool Corporation Ltd., of London, W.11, who have been appointed the sole selling agents. The winder has been designed to wind stators with a minimum bore diameter of $\frac{3}{8}$ in. up to a maximum bore diameter of $\frac{15}{16}$ in., with a maximum outside diameter of $1\frac{3}{4}$ in. Wire sizes down to 46-gauge (0·0016 in.) can be handled.

In operation, the stator is mounted horizontally in a special former or nest, clamped lightly into position, and adjusted so that the wire lays into the slots required. A wiring needle reciprocates horizontally to speeds up to 300 strokes per minute and also oscillates to lay the wire into the required slots, i.e., 1 to 4, 1 to 6, etc. After winding each coil, the stator is turned to the next position

Micro Hardness Tester



Swirl
Electrolytic Polisher



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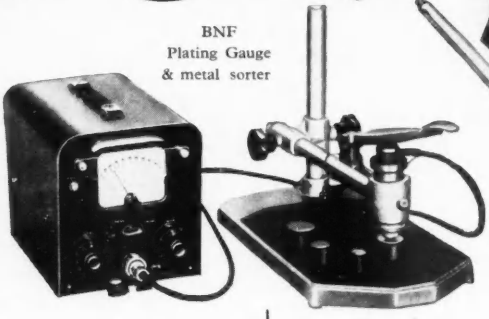
& metal sorter



Specimen
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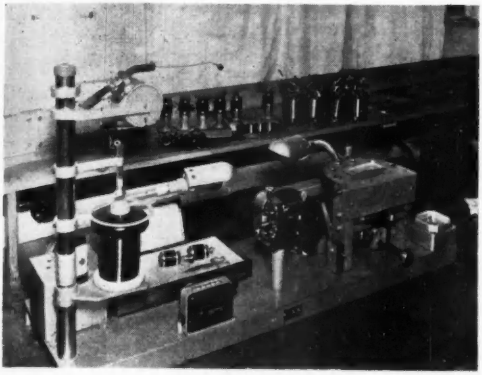
by the operator. The wire is positioned by highly polished formers or shrouds at either end, and these formers are developed to suit each particular type of stator. The machine is powered by a fractional-horse power electric motor. The speed of the winding needle is infinitely variable and is controlled by finger-tip pressure to ensure smooth starting and smooth acceleration.



The pay-off reel is mounted vertically with a light-alloy spinner plate, free to revolve on a ball race, while a special restricting device stops snarling or looping of the wire and allows the lightest gauge to be de-reeled without breaking. The wire then passes through a tensioner, the "fishing-rod" action of a spring wire guide taking up the slack as the needle reciprocates, so that an even tension is applied at all times.

Automatic pH-Control Water-Treatment System

By means of a new instrumented water-treatment system designed to eliminate the stoppage of the plant as a result of evaporator scaling or carbon dioxide corrosion, the low-pressure unit evaporators installed in the recently opened Willington "A" power station near Derby are expected to have a completely uninterrupted working life. The system, which has been instrumented by Honeywell Controls Limited, co-ordinates the control of flow and pH-values in such a way that the water entering the evaporators is kept at a constant pH-value, predetermined to ensure optimum working conditions. The plant on which this control equipment operates was supplied by the Neckar Water Softener Co. Ltd.

Unique in the U.K., the control system regulates the action of a two-stage treatment of the incoming town-water, which is initially softened in a base-exchange softener and is then dosed with an automatically controlled flow of acid to decompose the bicarbonate present. The acidified softened water is then fed into a degassing tower, where the free carbon dioxide is liberated. The degassed water, which still contains a trace of carbon dioxide, together with a slight excess of acid, is then drawn off from the degassing tower sump and is alkali-injected to the required pH-value before the final treated water is pumped to the storage tanks, whence it is fed to the evaporators.

An orifice plate and differential-pressure transmitter are used to measure the flow of water through the entire plant. This flow is recorded and integrated, and is automatically controlled by means of a diaphragm control valve. The liquid level in the degassing tower is also indicated and controlled pneumatically with a diaphragm control valve. The pH-values are recorded and pneumatically controlled for both stages of the treatment process. The method of control is novel in that flow and pH-value control are co-ordinated by means of averaging relays.

The rate of acid dosage is governed by the average of the signal from the liquid-level controller (approximately proportional to flow) and the controlled air output from the pH-controller. A second relay, which is manually adjustable, allows the acid-dosage rate to be varied to accommodate changes in the total alkalinity of the untreated town-water. The acid-dosing system can thus be reset to suit the varying qualities of the feedwater from different sources in the Derby area. The alkali dosing rate is governed by the average of the flow-transmitter signal and the controlled air output of the second pH-controller. The new control system has been found to keep the pH-value constant to within 0·2 pH.

Automatic Xerographic Copying Machine

Based on the xerographic process pioneered by Haloid Xerox Inc., of Rochester, N.Y., the new "Xerox" type-914 office copying machine manufactured in England by Rank-XeroX Limited, of London, W.1, is a fully automatic machine which produces high-quality black-and-white copies on ordinary plain paper from any type of original, irrespective of whether it is written, typed, printed, stamped, or drawn in any colour, including red and blue.

As xerography is a completely dry process, the prints emerge (at the rate of six per minute) ready for immediate use. Furthermore, the prints are permanent and all are of equally high quality, as the machine requires no adjustments for exposure or development, so that errors in judgment on the part of the operator are impossible. Another advantage of the machine, which is of neat and compact design, as shown in Fig. 1, is that the operator does not handle the copy paper or re-handle the original

Fig. 1

The Southern Instruments system

Auto Processor

A completely self-contained machine which develops, fixes, and dries photographic paper record at high speed without a darkroom. Records up to 200 ft. long and 6 in. wide may be processed by one charge of chemicals. The machine will also process a number of narrower width records simultaneously. A rewind unit is available as an extra.

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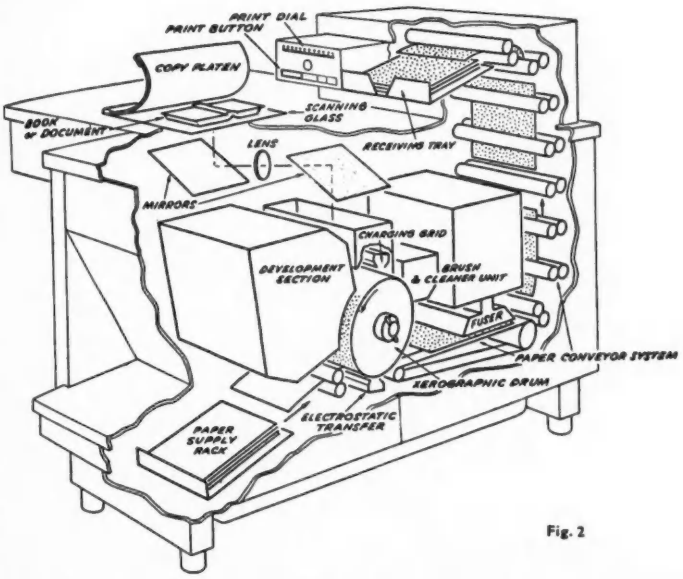

Fig. 2

for mutliple copies, as the number of copies desired is selected on a dial and is automatically delivered on completion. The original can be anything from a letter to a bound book.

The principle of operation of the machine can be appreciated from the cut-away view in Fig. 2. The original document or book is placed on the scanning glass and covered by the copy platen, and the desired number of copies is selected on the print-dial. When the push-button is operated, the positively charged xerographic drum, which is coated with a layer of photosensitive selenium, rotates in the direction indicated, the copy image projected through the optical system on to the surface of the drum forming a pattern of electrostatically charged and discharged areas corresponding to the original image. The latent electrostatic image is developed when oppositely charged dry powder is cascaded over the drum. The powder adheres to the image and, as the copy paper comes into contact with the drum, the negatively charged powder image is transferred by placing a positive charge on the paper. Finally, the image is fused permanently to the paper by passing it under the enclosed heating grid, after which the finished print is conveyed to the delivery tray.

Electronic "Storekeeper" for Factories and Offices

In very large organizations, an electronic form of storekeeping can be, and in some cases is, employed. However, the cost of such an instrument, usually specially designed for a particular application, is very high and, although more than justified in such instances, the cost would be entirely prohibitive for smaller organizations. It is for this reason that the new electronic "storekeeper" announced by the Electronic Machine Co. Ltd., of Thornton Heath, Surrey, has been devised. This machine, which is essentially a desk-sized specialized computer, has been designed to retail at such a low price as to make it an attractively economic proposition to a large number of factories, warehouses, offices, etc., for whom, until now, electronic methods of storekeeping have been too costly and bulky. Nevertheless, despite its small size and reduced cost, the machine has a very large capacity. Thus, the basic machine illustrated is capable of recording and storing no less than 10,000 individual items under each of 5000 catalogue headings, so that it can keep stock of up to 50,000,000 individual items. Larger models are available for other article and catalogue requirements.

Initiation of all records is effected through the medium of a permanently incorporated electric typewriter, specially adapted to initiate the recording of information and also to type all associated information on such documents as goods inwards or outwards, advice notes, invoices, dockets, etc., as it is adaptable for the handling of all suitable types of continuous stationery or single sheets. By pressing an initiation tab and a plus or minus tab, followed by the catalogue number, a recording drum is prepared for the acceptance of the quantity of articles to be added or subtracted, manipulation of the following keys causing their number to be recorded. The top row of illuminated digits then shows the quantity of goods being placed in or taken out of stock, while the lower line of illuminated digits shows the number of items in stock under that particular catalogue heading before the new stock movement is recorded. The machine then calculates the new stock position, and the electric typewriter comes into operation, giving a typed record of these figures on the form inserted. Only one half of the platen is used, the other half being available for documentary typing.

In the event of requiring, without movement of stock, to know what stock is in any or all of the catalogue numbers, this can be checked by the use of appropriate tabs and keys, each answer coming up on the lower line of illuminated digits whilst being typed on the stock form.

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New Materials, Processes, and Equipment

Lathe with Constant Surface-Cutting-Speed Mechanism

A new type of constant surface-cutting-speed mechanism has recently been developed by The Monarch Machine Tool Company, of Sydney, Ohio, for their "Mona-Matic" manufacturing lathe. Functioning in conjunction with a four-cut fully automatic work cycle, controlled by a "multicycle programmer", this mechanism provides automatic variation of the speed of the drive motor to maintain the desired surface cutting speed on the various diameters and contours of each workpiece in the run. It is claimed that this new speed-control feature gives greatly increased tool life, higher rates of production, and improved workpiece finishes.

During operation, when the multicycle programmer of the lathe indexes from one cutting cycle to the next, causing the cutting tool to be automatically positioned for the required cut, an electrical signal indicating the exact distance from the cutting-tool tip to the workpiece centre-line is transmitted to the constant surface-cutting-speed mechanism, which then automatically adjusts the speed of the drive motor and hence the speed of the spindle. If, during the actual cut, the drive motor deviates from the proper speed, a special feedback signal system enables the control to compensate for the error.

Similarly, when contours are turned under the control of an "air-gauge tracer" unit on the new lathe, the constant-speed mechanism continually varies the speed of the drive motor, automatically maintaining the required surface speed at the point where the tool tip is actually cutting. The mechanism can, however, be controlled manually at any time, if desired. The dual-template air-gauge tracer assures template control for the last rough cut and final finish cut, with adjustable stop dimensioning of the first and second rough cuts. Actuation of the rough-cut stops and shifting of the template holder are controlled by the multicycle programmer.

Workpiece set-up time is reduced by a special interlocking system between the air-actuated tailstock and the air chuck on the headstock spindle. A single control lever at the tailstock moves the tailstock centre into the work, clamps the air chuck, and locks the tailstock spindle. Two support members installed between the headstock and tailstock legs give extra rigidity to the bed structure and absorb vibration.

The electrical control equipment of the constant-speed mechanism is housed in a separate cabinet enclosure, positioned near the drive-motor end of the machine, the main drive motor of the machine being a 25-hp variable-speed a.c. unit. Available surface speeds range from 200 to 1175 fpm and can be maintained over a 4 : 1 range of diameters. Optional equipment includes an independently powered chip conveyor for removing cutting chips into a centralized chip-disposal system.

Low-Cost Process-Control Computer

Representing a completely new approach to the design of an on-line analogue computer for the process industries, the "Anatrol" process-control computer announced by the Systems Engineering Group of De Havilland Propellers Limited, of Hatfield, Herts., provides for the first time a low-cost, comprehensive, and versatile system with the stability and robustness essential to modern on-line process control. The accuracy of the computer is compatible with current measurement accuracies, allowing it to be easily and efficiently integrated into existing control schemes, while its computing potential is equal to that of very much more costly and complex computer systems. Yet, despite these advantages, the computer measures only $28 \times 15 \times 23\frac{1}{2}$ in. high, and weighs only 180 lb.

In this computer, a minimum number of computing amplifiers and multipliers is formed into an arithmetical unit which is used to provide a step-by-step solution of equations, according to a preset programme, each step being selected sequentially by a switching system. Short stores are used to retain information on the result of a step in the solution for use in a later stage of the computation. Long stores are used to clamp the outputs at the last computed figure while fresh values are being determined. Up to a maximum of twenty-five steps is available, giving the computer the potential of a machine employing at least seventy-five computing amplifiers and twenty-five multipliers. Semiconductor techniques are used exclusively, with the exception of some electromechanical switching elements. The machine is based on module construction, and different component-unit combinations can be used, according to the problem.

The reduction in the number of expensive components used provides low cost and simplicity, and the use of semiconductor techniques enhances the reliability of the computer, which employs high-gain feedback amplifiers using high-performance transistor choppers to yield low drift over long periods. The active elements are transistors throughout. The amplifiers, which are used for computing functions and for providing "hold" facilities at the computer outputs, each have linearity and drift characteristics giving an overall error of less than $\pm 0{\cdot}1\%$ of full scale referred to each amplifier. At

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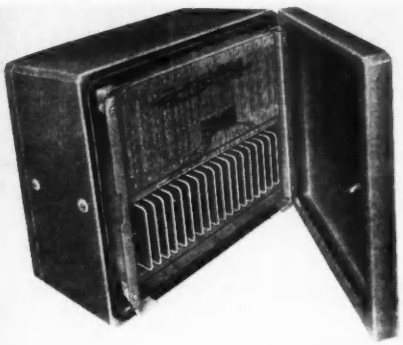
the first stage in each cycle, the computing amplifiers and multipliers are connected with the two voltage-reference units, which have an accuracy of 1 part in 104, and a null detector is used to check that overall accuracy is within specified limits. If this limit is exceeded, a signal for alarm purposes is given. The overall accuracy of the computer depends very much on the number of steps involved in the calculation and the form of arithmetic involved. In a typical problem the overall error will be less than $\pm 1\%$ of full scale, and this error can be reduced by the way in which a problem is programmed.



The computer, apart from addition and subtraction, multiplication and division, and multiplication and division by constants, is able to perform such functions as power laws (both fractional and whole numbers), differentiation by analogue methods or by taking differences, and integration by analogue methods or by time/amplitude sampling. Other functions, such as transcendental relationships, logarithmic and exponential laws, etc., can be handled by an additional input unit. These facilities make the computer suitable for process applications in which several variables must be operated on, according to a predetermined equation or other relationship, to yield a further variable which is a function of some input. Two computers can, if required, be operated in series or in parallel to increase the scope and size of the problem undertaken. In fact, the output from one machine can well form one of the inputs to the next machine.

Electrical Actuators for Valves

Suitable for the automatic, remote, and local powered control of a wide variety of valves, including parallel slide valves, globe valves, plug valves, butterfly valves, diaphragm valves, and wedge and gate valves, with rising spindles or non-rising spindles, the new Jones Tate Series-100 SD electrical actuators, announced by Dewrance & Co. Ltd., of London, S.E.1, provide instant availability of hand or power operation, with full safety interlock and automatic transfer from hand operation to power operation as soon as the motor circuit is completed, the handwheel being disengaged without shock or impulse being felt by any person attempting manual operation. Furthermore, the motor is permitted to start up and attain full speed before taking up the load, with instantaneous motor reversal under no-load conditions.

The actuator incorporates a torque switch for seating, with a wide range of adjustment, so that the seating load to seal the valve completely is correctly controlled. Coupled with the torque switch, which acts as a protection for both the valve and the actuator, is a special repetitive "notching" feature, the two devices being so arranged that notching or controlled hammering is available throughout the valve traverse until seating commences, when the torque switch becomes effective. The torque switch can be arranged to be operative in both directions of traverse or, if required, it can be made operative throughout the full traverse, i.e., independent of normal limit-switches.

In the case of parallel slide valves, the valve operating mechanism comprises an electric motor coupled by straight-tooth gears to the valve spindle by a centrifugally controlled transfer clutch and a notching clutch, the centrifugal device transferring the drive from the handwheel to the motor gearing as the power is switched on and off. The notching clutch has self-releasing teeth which prevent the valve from being power-overloaded. The centrifugally controlled clutch allows the motor to attain full speed before the load is applied and also disconnects the motor as soon as the current is switched off, either by limit switches or the torque switch. Disengagement of the drive prevents drift and valve overtravel, and at the same time permits the kinetic energy of the rotating parts to be absorbed by a Belleville-washer pack. The limit switches are of the geared quick make-and-break type, driven by spur gearing from the second reduction shaft, and requiring only a small movement of the valve for both tripping and resetting. With appropriate operation of the controller, the motor accelerates, the handwheel automatically disengages, and the drive is transmitted to the valve spindle via the centrifugally controlled clutch and the notching clutch.

In the event of an excessive load, such as the valve being jammed, the notching-clutch teeth disengage, the actuator motor accelerates, and a torsional impulse or hammer blow is administered when they again engage. This hammering effect applies approximately twice the full-load torque to the valve, and the sequence continues

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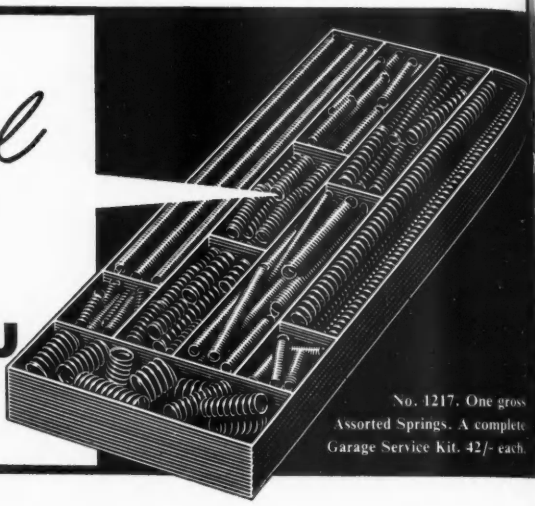

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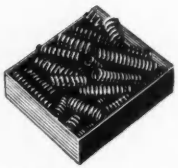

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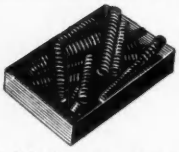

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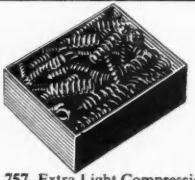

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repeatedly until the excessive load is overcome and normal traverse can continue. When the power is cut off, either by the controller or limit switch, the motor is de-energized, and the centrifugally controlled clutch automatically withdraws the drive from the motor and transfers it to the handwheel, ready for manual operation.

In the case of globe valves, and wedge and gate valves, the mechanism is similar to that described above for operating parallel slide valves, but includes a torque limit-switch designed in conjunction with a Belleville spring-washer pack. Immediately before seating commences, the torque switch is brought into operation, the sealing thrust imparted being a function of the torque applied to the valve spindle. The applied torque is measured by the separation of the notching-clutch teeth, and this motion is applied to the torque switch. Thus, when the torque reaches a predetermined figure, the torque switch trips and de-energizes the actuator. The kinetic energy of the moving parts is absorbed by the Belleville-washer pack, which also exerts the thrust to keep the valve dead-seated after switching off the actuator.

These actuators are available in standard totally enclosed weatherproof versions, or as flameproof and weatherproof versions, in nine different sizes, ranging from maximum spindle diameters of 1¼ to 4½ in., with corresponding thrust ratings from 12,000 to 150,000 lb, and nominal torque values at the normal maximum valve-spindle speed of 24 rpm from 60 to 3500 lb-ft. These units are normally suitable for operation at temperatures up to 140° F, though actuators suitable for higher ambient temperatures can be supplied to special order. The illustration shows the 120 SD flameproof and weatherproof actuator, with a nominal torque rating of 120 lb-ft at 24 rpm.

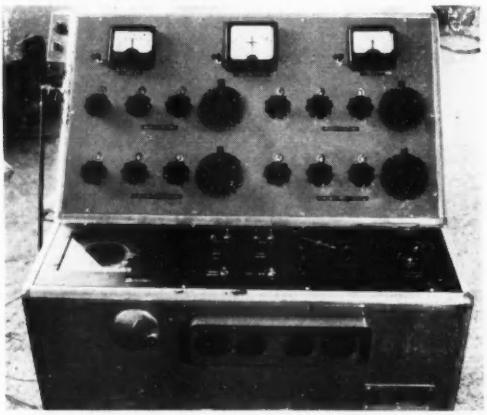
Control Equipment for Machine Tools

Extremely reliable and accurate in operation, "Teledictor" control equipment for machine tools, produced by Teledictor Limited, of Tipton, Staffs., is designed to cover a wide range of applications. Thus, most types of machine tool, such as radial drills, lathes, milling machines, and gear-cutting machines, can be satisfactorily controlled by this equipment. Also, a predetermined sequence of control settings, i.e., a programme, for an article can be established, so that the quality of the finished product is invariably consistent. The control equipment can be operated manually or, by using punched cards, automatically.

By using analogue principles in the control equipment, any given setting of the machine tool can be represented by two voltages which are directly related to either the cartesian co-ordinates of the setting, or, for certain applications, the polar co-ordinates. In this way, the control equipment always "knows" the exact setting of the machine tool, so that any changes, corrections, or modifications which may be required during a machining procedure can be made without the necessity for repeating the entire programme.

A fairly simple positioning control forms the basis of the control equipment and enables the machine tool to be operated to any desired position, e.g., for drilling. The appropriate co-ordinates are set by means of controls on the equipment console, and two servo-motors (independently switched) drive the machine tool to the corresponding position. Normally, cartesian co-ordinates are used, three switches and a potentiometer (referred to as the "base" controls) being associated with each of the two co-ordinates to facilitate settings between 0 and 10 in., the smallest scale divisions representing 0·0001 in.

In order that the article to be manufactured need not be accurately positioned on the machine bed, datum controls are incorporated, these controls being adjusted at the commencement of a programme to align the machine tool to a predetermined reference point on the article. In this way, the article can be secured in virtually any position on the machine bed (provided that parallelism with the bed edges is observed), the base settings being referenced to the datum settings. For quantity work, the datum controls are set for the first article, and locating blocks are then fitted to the machine-tool bed. Two centre-zero meters (one for each co-ordinate) indicate when the machine tool has reached the position determined by the base settings.



A shape generator can be included in the console for performing such functions as cutting circles or straight lines at any angle. By suitable programming, a cutting tool can be made to cut complicated shapes involving circular curves and straight lines. A shape generator can also be provided for arbitrary curves, the generator being set up for the particular requirement on site.

Stable Bright Platinum Plating Solution

A stable platinum plating solution, from which bright, heavy, and coherent deposits can be obtained, has now been made avilable by Johnson, Matthey & Co., Limited, of London, E.C.1. This bath, known as DNS platinum plating solution, is based on the complex sulphatodinitrito-platinous acid $H_2Pt(NO_2)_2SO_4$, and is acidic in nature, so that it can be used successfully on electrical components and on printed circuits. Platinum from the solution can be deposited directly on to copper, brass, silver, nickel, aluminium, and titanium; for deposition on tin, zinc, cadmium, or steel, an undercoat of silver or nickel is necessary. Deposits from the new bath, which requires no agitation, are exceptionally bright and lustrous at all thicknesses, and no polishing is required. No evidence of porosity has been found in deposits up to 0·001 in. in thickness on polished copper but, above this thickness, some evidence of cracking may be observed. Microhardness tests on deposits have given values ranging from 400 to 450 VPN. The character of the deposits remains unchanged in a temperature range between 30° and 70° C, but the recommended operating temperature is 50° C.

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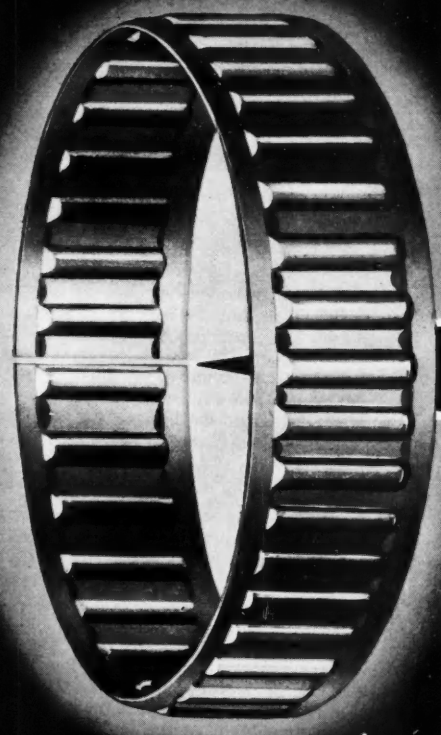

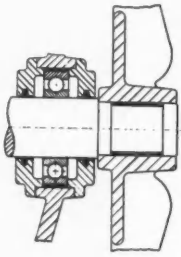

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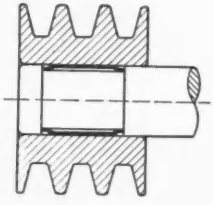

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New Transistor-Chopper Technique

Largely overcoming earlier objections to the use of transistor-choppers for field work, such as the need for accurate prior setting up to obtain a low and constant rate of drift with changes in temperature, a new technique for using a symmetrical transistor as a chopper has been developed by Smiths Aviation Division, of Wembley, Middlesex, principally for use with thermocouples, though its use in strain-gauge work is also visualized. In fact, it is stated that the new technique has changed the application of transistor-choppers in circuits suitable for laboratory work to circuits which can be used in robust instruments capable of withstanding the rough conditions of general work.

With the new technique, setting up is obviated or, for certain applications, reduced to a minimum, and performance can be guaranteed from a standard batch of transistors. Thus, using silicon transistors, a drift rate of better than 1·5 $\mu V/^\circ C$, without selection from a batch or setting up, is claimed over a temperature range between —40° and +100° C. With limited setting up, the results are stated to be better than 1·0 $\mu V/^\circ C$ under the same conditions. In addition, the weight of the transistor-chopper is less than that of a mechanical chopper, while the transistor-chopper circuit, which includes two transistors, four resistors, and one transformer, is about 25% of the size of a mechanical chopper.

New Ultra-High-Strength Steels

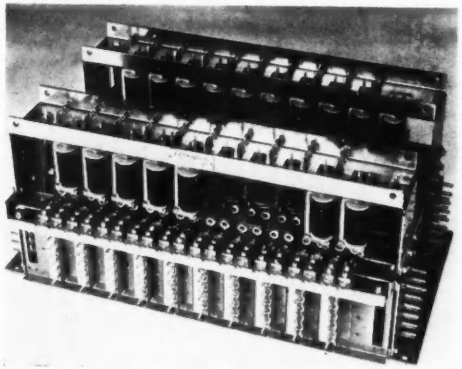
Designed to give tensile strengths of between 100 an 140 tsi after tempering at up to 600° C, a new series of ultra-high-strength steels for use at high temperatures has been developed by Samuel Fox and Company, Limited, a subsidiary of the United Steel Companies Limited, of Sheffield. In addition to permitting higher operating temperatures to be considered in design, compared with steels currently specified for these strength levels, the high tempering temperature of these new steels yields maximum stress relief and hence greater dimensional stability.

At present, there are three steels in the new series, though one of these is a commercial alloy already in production. Formerly designated Fox 769, but now renamed HST 100, this steel has a tensile strength of 100 tsi in the air-hardened and tempered condition, and the two entirely new steels in the series have, in fact, been obtained by small compositional changes in the basic HST 100 analysis, coupled with the use of a combination of solution hardening and improved tempering resistance. The two new steels are known as HST 120 and HST 140, and have tensile strengths of 120 and 140 tsi respectively. Compared with HST 100, these steels do not have an increased carbon content; indeed, it has been found possible to reduce the carbon content of the HST 120 steel to 0·30%. Both steels can be hardened in air or in oil, depending on mass, and all three in the series have silicon contents below 0·40%.

These steels can be produced in the form of billets, blooms, and slabs for forging and re-rolling, and in bars for forging or machining. Bars can be supplied in either the annealed or the fully hardened and tempered condition. Experiments are taking place to produce sheets down to 0·064 in. in thickness in all three qualities, but these are not as yet generally available.

High-Frequency Crossbar Switch

A new high-frequency crossbar switch requiring limited space and eliminating the need for bus wiring has been introduced by James Cunningham Son & Co., Inc., of Rochester, N.Y. The new switch, designated the Cunningham Type P, has specific applications in radar, sonar, and low-level signal distribution and, because of its design flexibility, is available in a variety of modules to meet specific requirements.



Measuring only $4\frac{3}{8} \times 12\frac{1}{4} \times 2\frac{5}{8}$ in. and weighing about $4\frac{1}{2}$ lb, the basic unit can switch sequentially or at random up to 120 circuits. Individual magnets at each crosspoint make an electrical connection at the crosspoint, closing a circuit in one input and one output. Any circuit combination can be set up in any sequence and each circuit can have up to six poles. The twin gold contacts used can carry 100 mA non-inductive load at 50 V d.c. for 20,000,000 operations. Contact bounce on make is less than 200 microseconds, and no bounce at all is discernible on break.

Multiplane Diffractometer for Preferred-Orientation Work

Based on a design currently in use at the Atomic Energy Research Establishment at Harwell, a new multiplane diffractometer for fully automatic or manual operation has been designed and produced by Seton Creaghe Engineering Ltd., of London, N.W.10. Apart from its use in the field of nucleonics, the new instrument, which incorporates goniometric and scanning movements for fulfilling the requirements of rapid operation and

we had this taped from the start

Amongst the large number of moulding jobs we have carried out we include this 12″ Magnetic Tape Reel and Transparent Dust Proof Cover* as one of the more interesting.
The moulding is a typical example of accuracy combined with size and attractive appearance. One of the salient features in the moulding is the fitting of the top cover to the base by three latches. A PTFE Washer (.005″) was included which eliminated the need for lubrication.
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An interesting factor is the range of material used:

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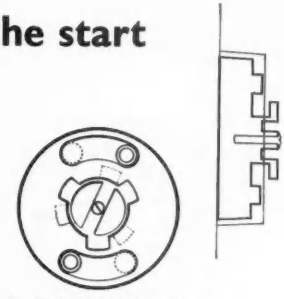
Locking Ring: *Polythene.*
Washer *P.T.F.E.*



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extreme accuracy, is also suitable for use in the chemical, mining, welding, and other industries where crystal-structure analysis is being carried out.

Essentially, the diffractometer is an X-ray instrument designed to use the Shulz method of determining the preferred orientation of crystals. This method enables the intensities of reflections to be related, without correction, to the number of crystals reflecting, so that the instrument can be used to examine the crystal structure of a specimen in any plane by the simple but precise adjustment of the goniometer ring. Setting up of the instrument is rapid, and no readjustments are needed when the plane of examination is altered. Seven simple adjustments are all that are required to prepare the instrument for use.

The main body of the instrument is carried on adjustable cross-slides by three levelling screws and can be further adjusted in angle to the base. The geiger-counter arm and goniometer ring are carried by concentric bearings and the gearing between them gives a 2 : 1 angular movement. The goniometer ring can be adjusted separately in relation to the counter arm and then clamped. Rotation of these items is by hand and two scales give the angle 2θ to one minute of arc.

Slit systems are provided for the incident and reflected beam, and are accurately located. Various angles of beam spread can be provided. Since the slit system is arranged in a simple geometric ratio, careful choice of slits can double the range of receptor and divergence angles. The goniometer has a scale inscribed to 0·5 deg. and carries the specimen holder and a beam width-limiting slit, provided as standard for preferred orientation. A special curved slit can be supplied for purely diffraction purposes. The specimen holder can be rotated and reciprocated in the beam by two variable-speed motors, the angle of specimen rotation and length of stroke being shown on scales. Specimen holders for rod, sheet, or tube specimens are available, and gauges are provided to position the specimen quickly and accurately. Tests have shown that the diffractometer is able to separate an α_1,α_2 doubtlet less than 6 ft apart.

Electronic Inspection Device for Rivet Heads

Developed by the Boeing Airplane Company, of Seattle, Washington, an entirely new type of electronic rivet-head inspection device can show, with an accuracy of 0·0001 in., any deviation from normal of any of the millions of rivets purchased by Boeing every year.

Up to now, the meticulous task of measuring sample batches and determining deviation has been accomplished by hand-gauging methods. In future, using the new device, it will be possible to measure a batch of 50 rivets and to arrive at an acceptance or rejection figure, automatically averaged and computed, in one-third of the time formerly required. Further speeding of inspection by means of automatic rivet handling and an improved computer, now in the design stages, is expected. In addition to reducing the time and cost of rivet inspection, and ensuring increased accuracy, the same electronic and electro-mechanical principles can be applied to other gauging operations.

The new inspection device consists essentially of a gauge block, a sensing head, and a simple electronic computer (shown in the illustration with its case removed). Before measuring production rivets, a master rivet is placed in the gauge block to set up a reference level, and

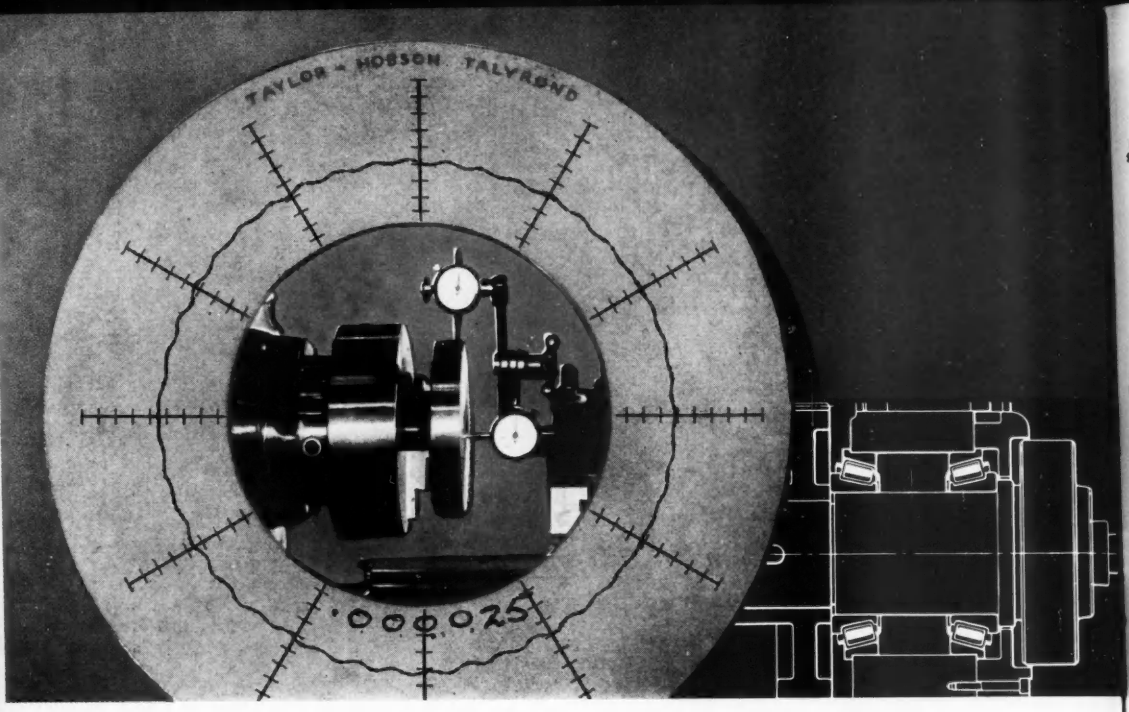
rivets to be inspected are then placed in the gauge block one at a time. In the sensing head (in the foreground of the illustration), a push-button drops a protrusion-measuring stylus onto the rivet head. Attached to the stylus, the movable core of an electro-mechanical transducer translates the measurement made by the stylus into an electrical potential difference which is proportional to the displacement of the stylus. This difference is amplified and supplied to the computer, which determines any deviation, first for each rivet, and then for the batch as a whole.

Miniature Electromagnetic Circuit-Breakers

The new range of Type C-50 miniature circuit-breakers announced by J. A. Crabtree & Co. Ltd., of Walsall, Staffs., may well challenge the use of rewireable fuses for sub-circuit protection, inasmuch as these circuit-breakers are high-efficiency units produced at a really competitive price and in a size suitable for use in domestic consumers' units or distribution boards. Indeed, they are claimed to be the first all-insulated domestic consumers' units to embody circuit-breaker protection.

The new circuit-breaker has an electromagnetically operated trip mechanism, all ratings being set to trip on a sustained 30% overload. An essential feature is a built-in inverse time-current delay device which prevents harmless transient overloads from causing "nuisance" tripping, though the same mechanism ensures instantaneous tripping under heavy overload or short-circuit fault conditions. Thus, whilst tolerating harmless transient overloads, the circuit-breaker gives close and accurate overload protection against any form of sustained overloading. An important feature is that neither the minimum tripping current nor the nominal current rating is affected by variations in ambient temperature. Not only do these values remain constant, but, in addition, all current ratings, including the lower ranges, maintain their accurate tripping characteristic after successfully clearing repeated overload or short-circuit faults.

The operating handle of the unit controls a moving contact through a collapsible, over-centre toggle mechanism. As this handle is in positive control of the movement in both the on and off positions, the breaker can always be manually opened or closed. As the breaker closes, a powerful main-spring imparts a high



High-precision bearings

Timken high-precision bearings are made expressly for machine tools and other applications needing great accuracy. The above photograph shows two of the tests on a Model 'D'

NO. 18 HOLBROOK LATHE;

the graph shows an enlarged Talyrond record, indicating the maximum out-of-round as ·000025″, the limit for this lathe being ·0001″. The 'camming' on the face was also ·000025″; other tests show comparable accuracy. These results are representative, the lathe being typical of the standard production. Full particulars of the three grades of Timken precision bearings, on request. British Timken, Duston, Northampton, Division of The Timken Roller Bearing Company. Timken bearings manufactured in England, Australia, Brazil, Canada, France and U.S.A.

Photograph by courtesy of Holbrook Machine Tool Co. Ltd., Harlow, Essex. Graph taken on Taylor-Hobson Talyrond. Sectional drawing shows the flanged Timken bearings on the front end of the work spindle: these bearings control the axial location in both directions.

TIMKEN®

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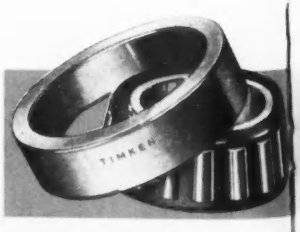
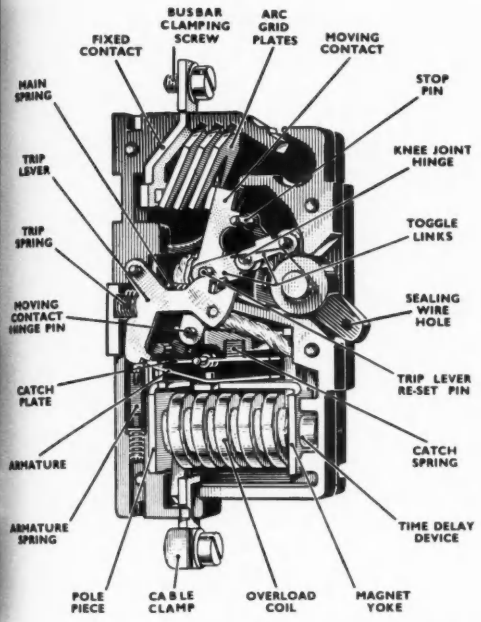
tapered roller bearings





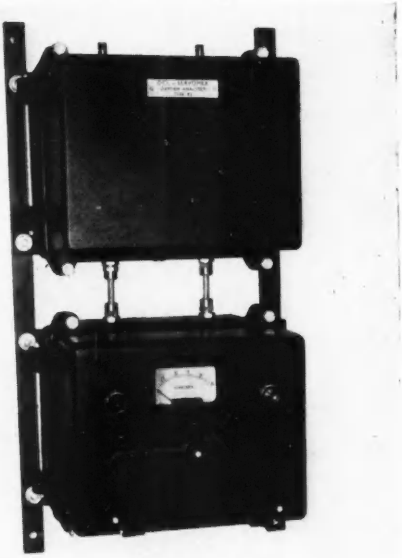
contact force, ensuring low heat losses and freedom from the danger of welding. Proving tests have already justified the issue of an interim breaking-capacity certificate of 3000 A (0·8 pF), 250 V. After these tests, all samples were in full working order, i.e., they proved capable of making and breaking rated current at rated voltage, of carrying rated current indefinitely, and of tripping on a sustained 30% overload.

Industrial Oxygen Analyser

Many oxygen analysers exist which use the paramagnetic property of oxygen, but most of these rely on what is called magnetic wind, i.e., a convection current in the gas, which is then measured by its cooling effect on a temperature-sensitive element. These magnetic-wind instruments have the serious disadvantage of being inherently sensitive to changes of thermal conductivity, viscosity, and tilting, and to the presence of combustible components in the sample. Moreover, their response time is of the order of minutes, owing to the sluggish movement of the gas.

These difficulties have now been overcome in the DCL-Servomex type-DCL.83 oxygen analyser, which, in addition, provides a much higher degree of accuracy by means of a special null-balance arrangement. In this connection, it should be mentioned that the use of a suspended test-body to measure the magnetic susceptibility of gases is precisely the method used by Faraday, and one American instrument uses the same extremely delicate quartz suspension used by Faraday, in conjunction with electrostatic feedback, whereas the DCL.83 analyser employs a much more robust rare-metal suspension carrying the feedback current, thus removing a very serious practical objection to this type of instrument.

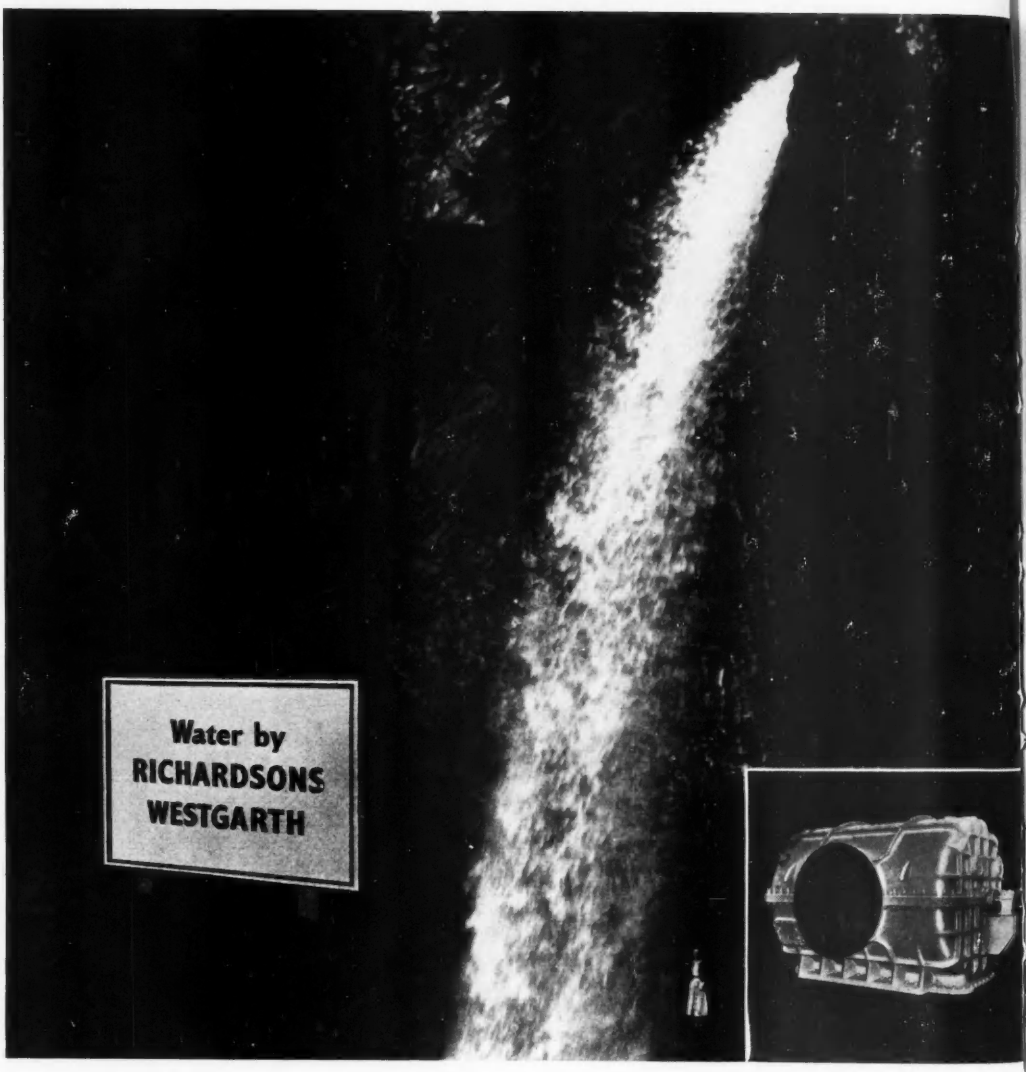
The new analyser utilizes the paramagnetism of oxygen and is therefore highly selective, the only other common gases which might affect the reading being nitric oxide and nitrogen peroxide. The test-body, made of silica, is surrounded by the sample gas and is suspended in a non-uniform magnetic field, experiencing a torque which is proportional to the partial pressure of the oxygen in the sample gas. This torque is counteracted by electromagnetic feedback produced by current flowing through a coil mounted on the test-body. The null position of the test-body is detected by a light source and a split photocell, the output of which is fed to a balanced d.c. amplifier to produce the current feedback. Linear ranges from 0 to 1% up to 0 to 100% oxygen are available by means of switching from the single instrument.



The use of a null-balance technique has the advantage that it gives freedom from effects caused by voltage fluctuations and ageing of components. Furthermore, it provides damping and enables the suspension to be made much more robust than is possible with a purely deflectional instrument, making the instrument insensitive to heavy mechanical shock and vibration. Other advantages of the new analyser are that it does not respond to variations in the thermal conductivity or viscosity of the sample gas or to variations in its flow rate. In addition, the instrument has a rapid response, and a high order of sensitivity, accuracy, and linearity is achieved, while the sample gas is not exposed to hot wires or high voltages, so that there is no risk of igniting inflammable mixtures or of causing catalytic effects to arise.

High-Intensity Electromagnetic Separators

A new range of high-intensity electromagnetic separators, specially designed for extracting feebly magnetic materials from non-magnetic materials, such as silica sands, travelling on existing conveyors, has been introduced by Industrial Magnets Ltd., of Birmingham 27. These separators are completely self-contained units, in sizes covering a range of conveyors from 12 to 48 in. in width, and a special feature is their adaptability



A single strainer of the type we supply to the C.E.G.B. handles five million gallons of water an hour—enough to maintain quite a spectacular waterfall. At Aberthaw Power Station there are six such units with a total capacity of 30,000,000 g.p.h. straining the condenser cooling water.

Richardsons Westgarth rotary strainers are made in a range of sizes from 160,000 g.p.h. to 5,000,000 g.p.h., they are self cleaning, operate continuously, and the accumulated sludge is blown out at intervals without interrupting the flow.

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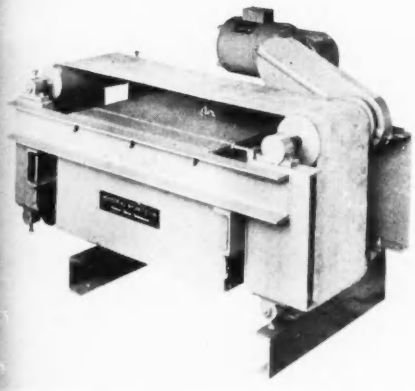
to incorporation into conveyor schemes, without requiring alteration to existing plant. Furthermore, a number of these units can be installed over the same conveyor, each unit having individual adjustment for the working gap, thereby enabling particles of different magnetic susceptibility to be extracted by each unit. Rheostatic control of magnetic intensity can also be arranged.

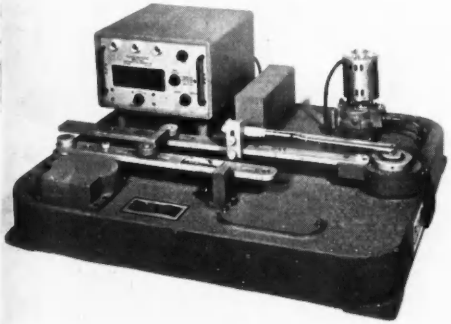


The separator, which merely requires the use of supporting stringers for installation, operates on the cross-belt principle, a robust framework carrying a high-permeability steel magnet unit with a totally enclosed high-conductivity copper magnetizing coil. The cross-belt, passing along the magnet poles immediately over the main conveyor burden, searches out and extract all magnetic particles from the material being processed and provides for their automatic discharge. The unit is virtually maintenance-free and includes a totally enclosed gear motor and chain drive. Belt replacement is exceptionally easy.

Torque-Wrench Calibrator

Capable of rapidly loading the actual "break-away" value of torque-wrenches of any design, a new torque-wrench calibrator developed by Steel City Testing Machines, Inc., of Detroit, Michigan, uses a conventional proving ring as a load-measuring standard and, for most torque-wrench designs, operates automatically.

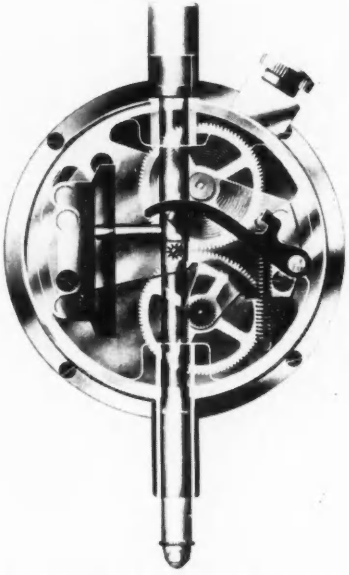
When a wrench is inserted into the mechanism, and load links and an electronic digital counter are set for the correct range, the tang is rotated by a hydraulic piston and cylinder assembly. The digital-counter translates the linear displacement of the proving ring into torque values with a calibration accuracy of 0·4% of full scale and, at the break-away point of the wrench, displays these values either in pound-inches or pound-feet. Torque-wrenches with capacities between 20 lb-in. and 2000 lb-ft can be calibrated in four ranges, i.e., 20 to 1000 lb-in., 1000 to 5000 lb-in., 1 to 500 lb-ft, and 500 to 2000 lb-ft. An adjustable thrust-arm can be positioned for any normal length of torque-wrench, and four interchangeable socket inserts accommodate standard wrench tangs.



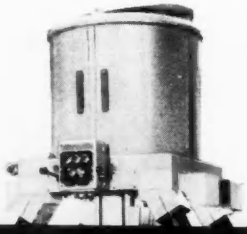
Dial- or clock-type wrenches which do not "snap" at the set torque cannot be checked automatically with this equipment, but can be manually calibrated quickly and without loss of accuracy.

Supersensitive Dial Indicators

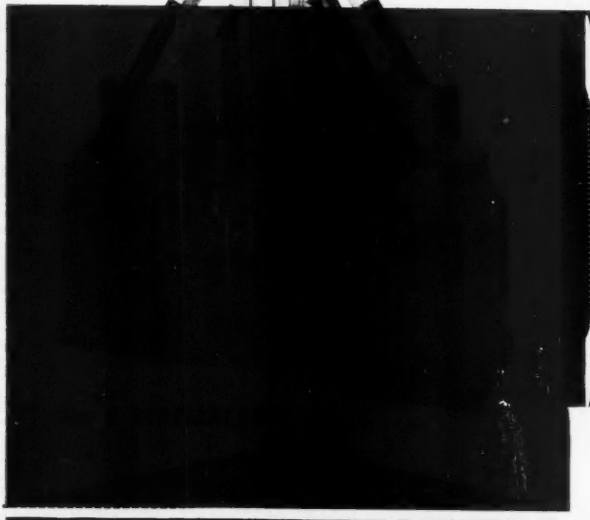
Available in four dial sizes, i.e., 1½, 2, 3, and 4 in., and in all recognized graduations, the new "John Bull" supersensitive dial indicators announced by British Indicators (Sales) Ltd., of St. Albans, Herts., are stated to provide a degree of sensitivity and accuracy which is far greater than that possible with any other dial indicator so far produced.

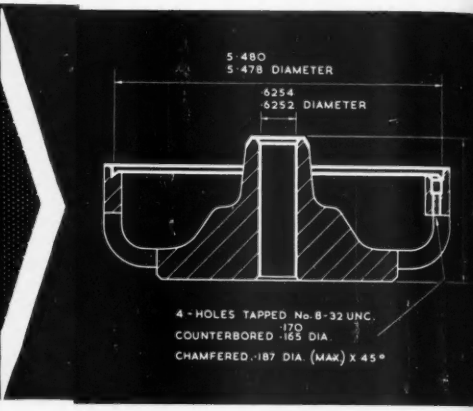


The case of the instrument is a casting of rigid section, with inserted hardened and ground stainless-steel stem bushes in which the super-finished rack spindle runs. The movement plates carry inserted interchangeable brass bearing bushes, and the pinions of the instrument are hardened and lapped throughout to provide a very high degree of sensitivity and accuracy. The rack return-spring lever is specially formed to provide constant tension throughout the travel of the indicator and is compensated against build-up of the return spring. This lever runs in a grooved guide-roller to minimize friction still further, whilst the gears themselves are of special instrument brass. The indicator hands (not shown in the illustration) is balanced to eliminate drag.



See how smoothly production





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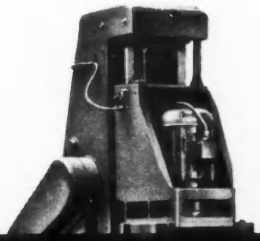

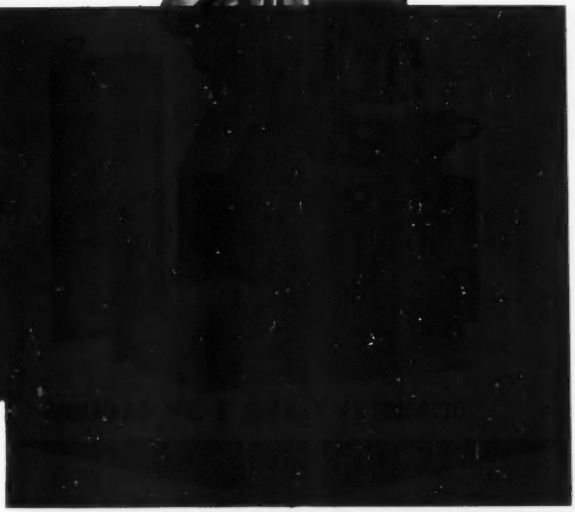

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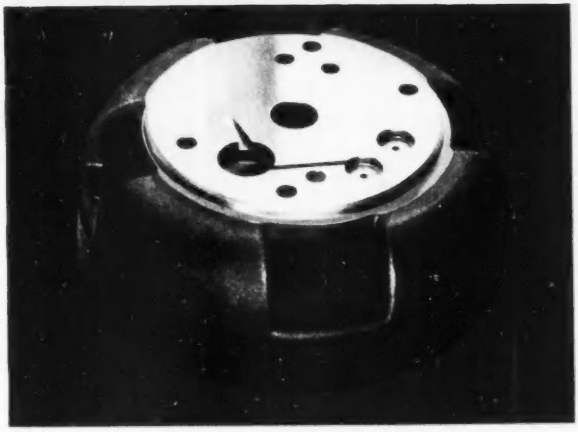

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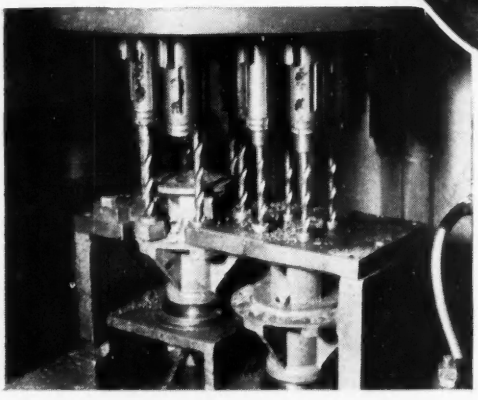

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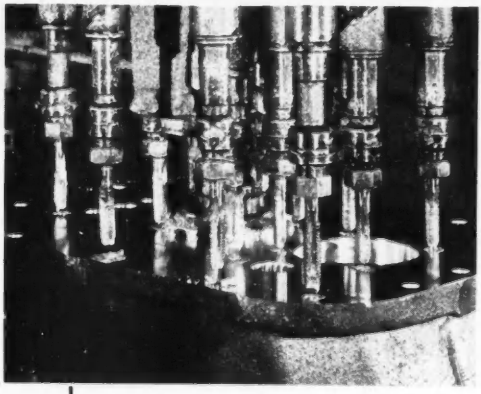

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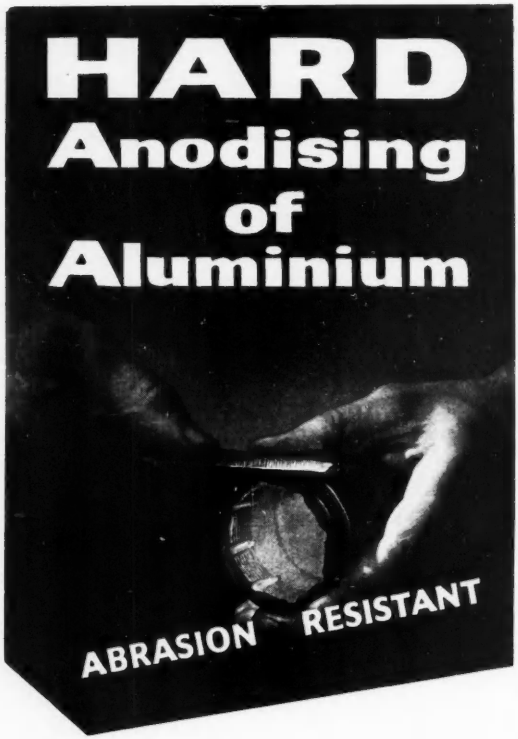

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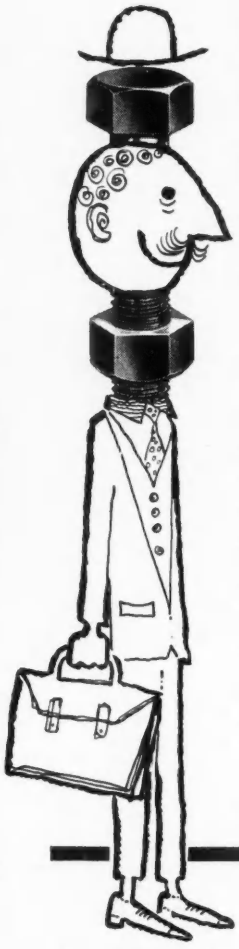

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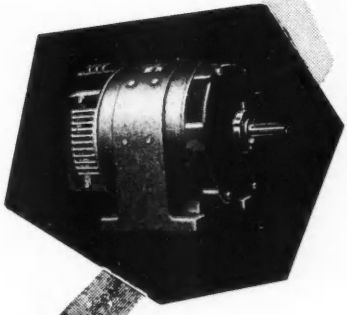

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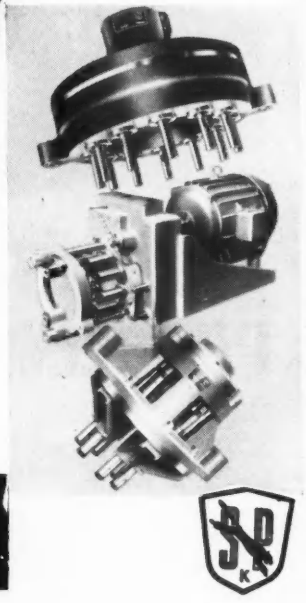

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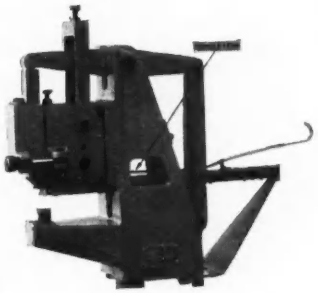
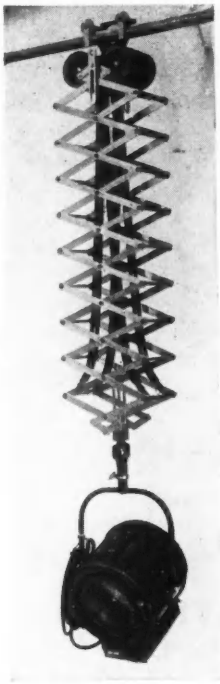


Constant-force Spring doubles cartridge length in this Stapling Machine by Lightning Fasteners Ltd. (subsidiary of I.C.I.).

Constant-force Spring gives ideal commutation with longer brushes whilst saving radial space, at economic cost.

Constant-force Spring smoothly and exactly counterbalances Transport Windows by Beckett, Laycock & Watkinson Ltd.



Constant-force Spring perfectly balances 75 lb. load through 16 ft., with provision for varying weight, in Studio Lighting Equipment by Mole-Richardson (England) Ltd.

Constant-force 'B' Motor Spring increases number of unwinding turns by 2½, and delivers torque at constant rate without intercoil friction, in 16 mm. Ciné Camera by Rank Precision Industries (B.A.F.) Ltd.

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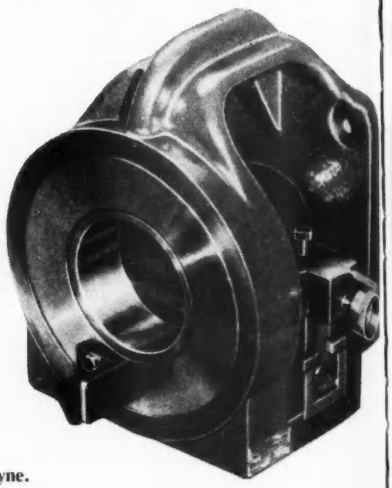

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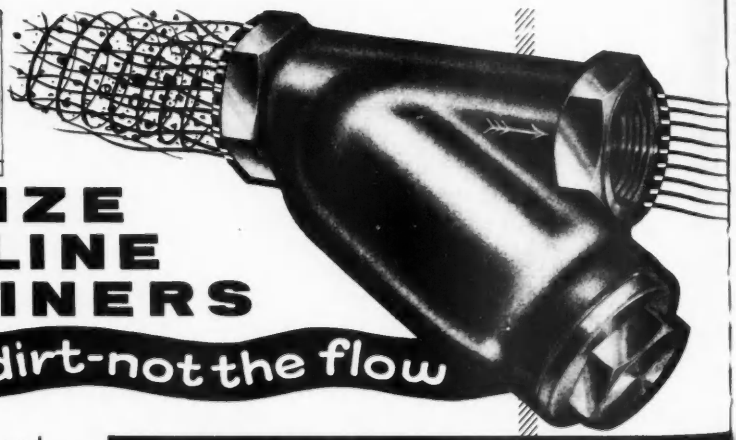

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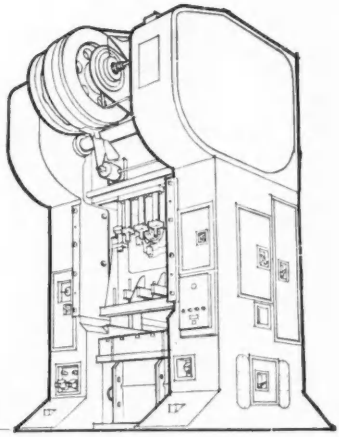

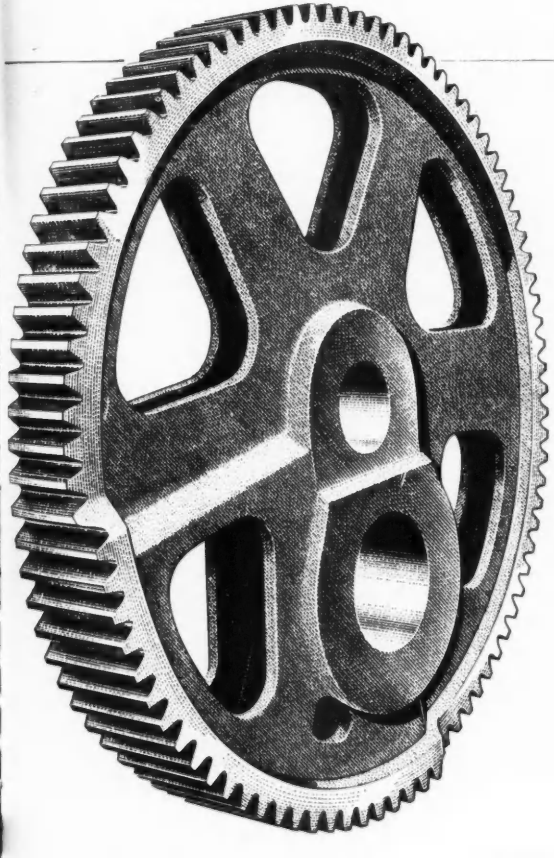

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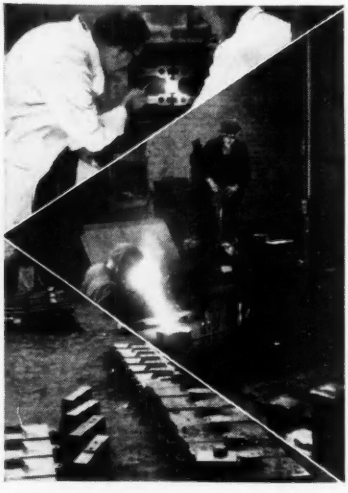

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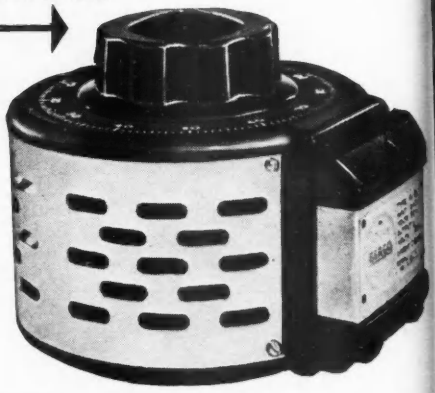

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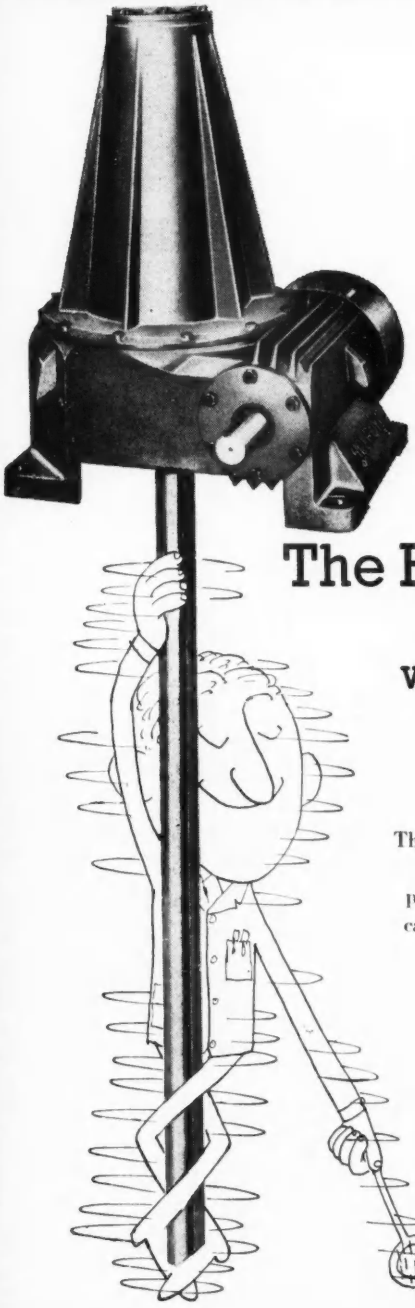

The Holroyd 'Top Hat'
holds the shaft steady while you stir things up

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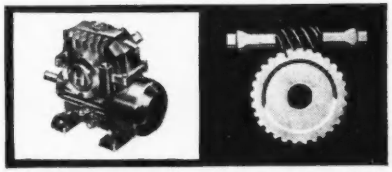
Holroyd



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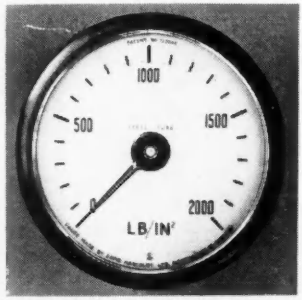

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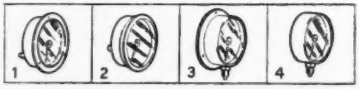

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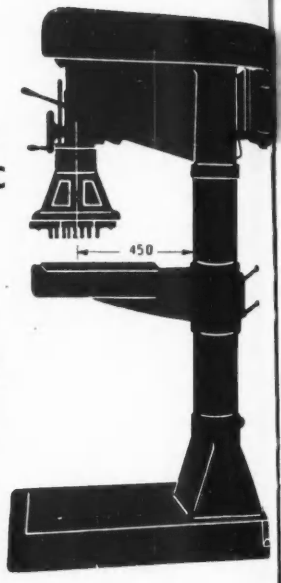

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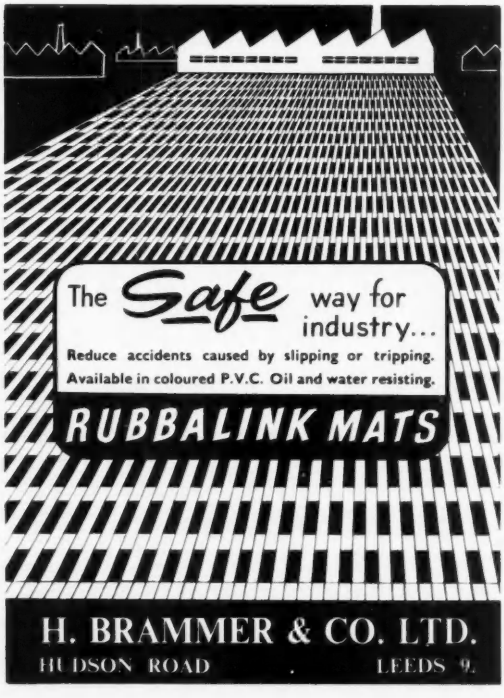
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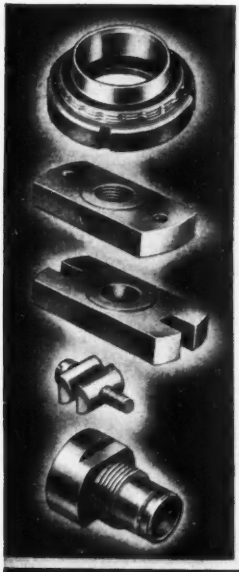

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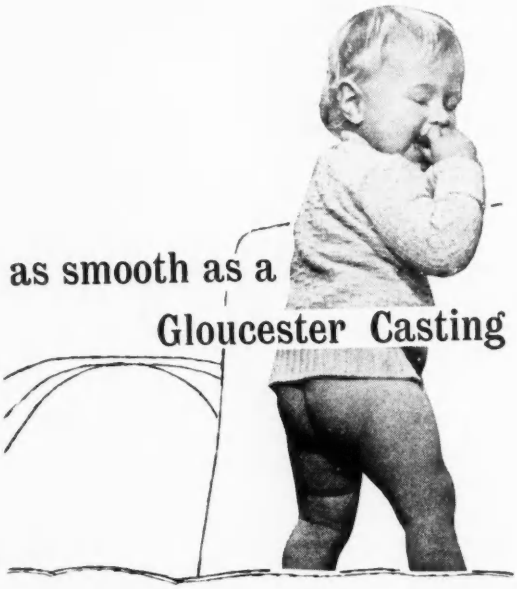

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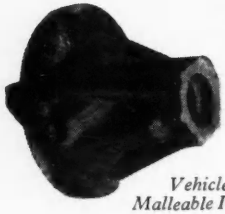

Right:
Spring mounting bracket in Malleable Iron Weight 8½ lbs.

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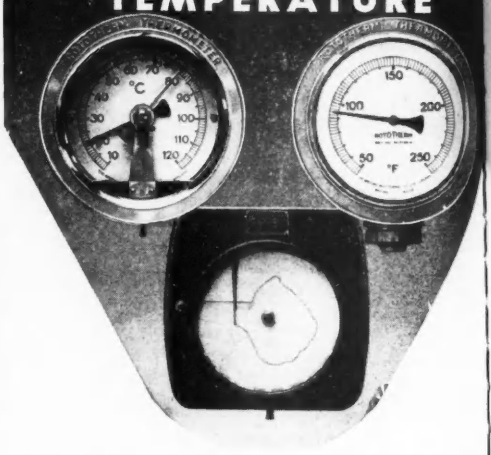

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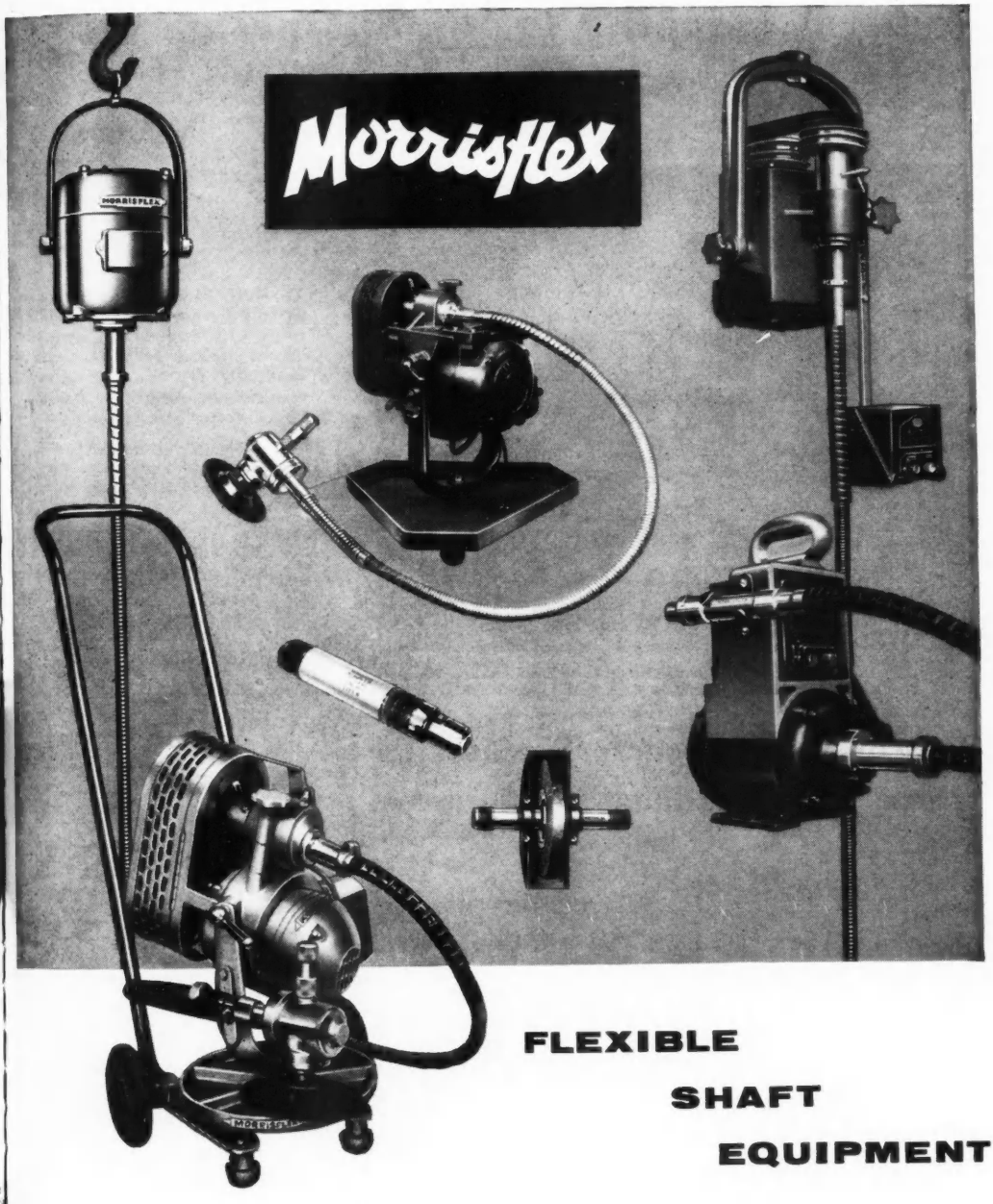

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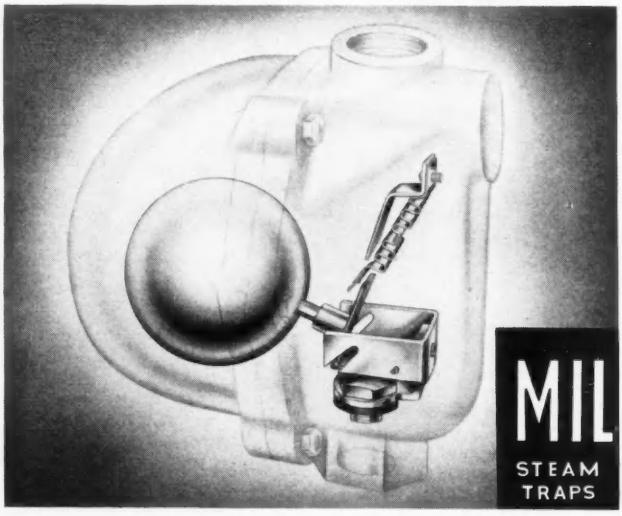

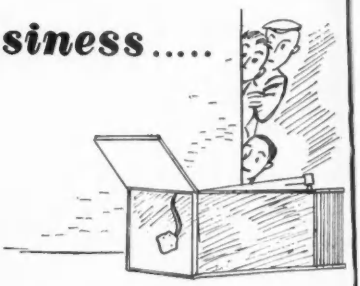

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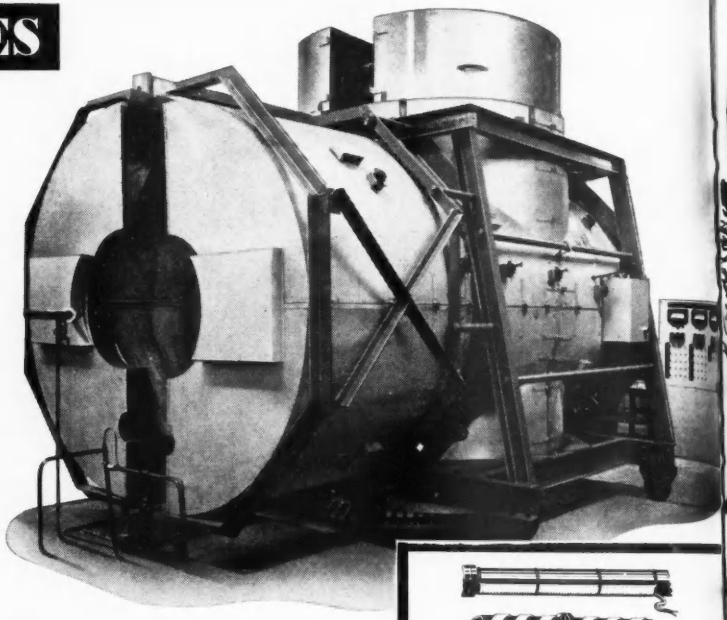

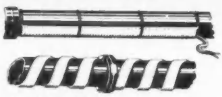

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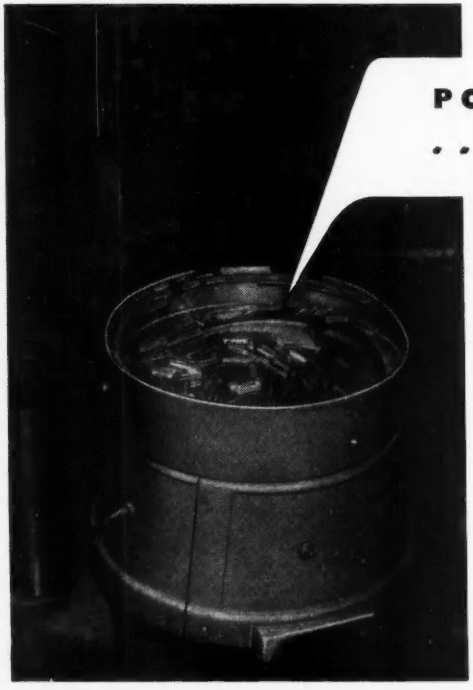

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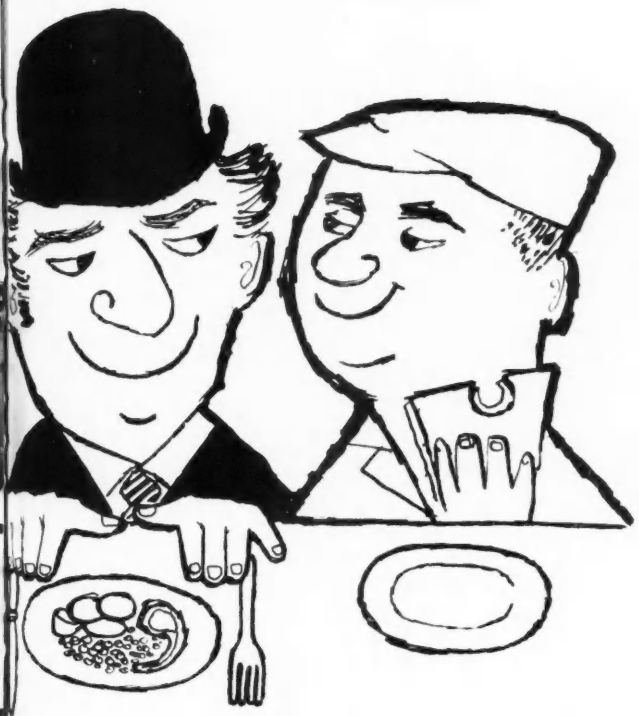

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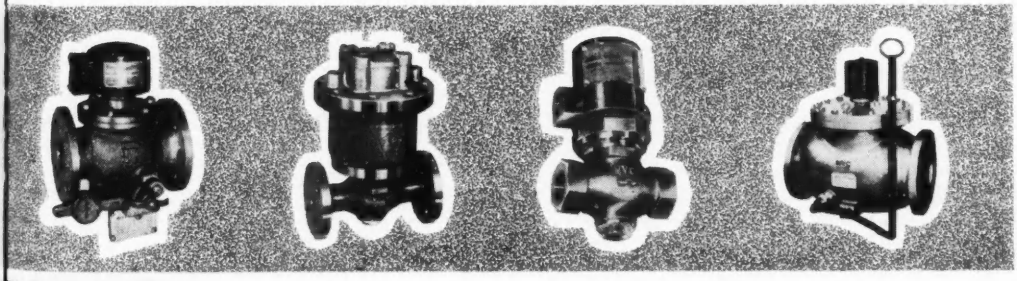

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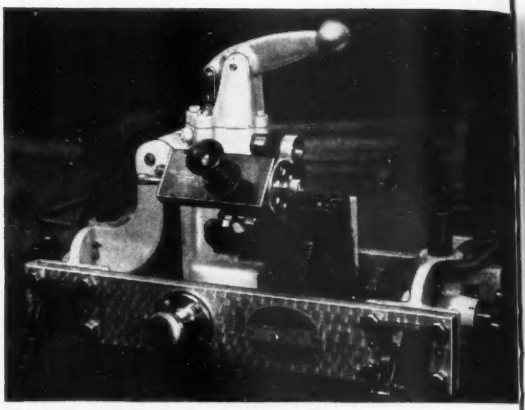

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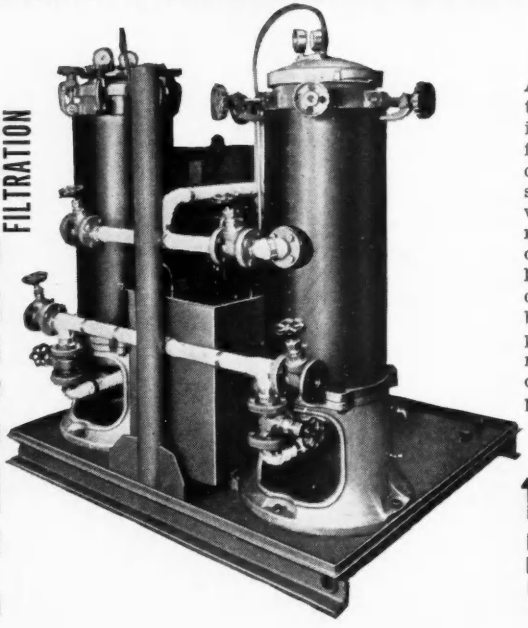

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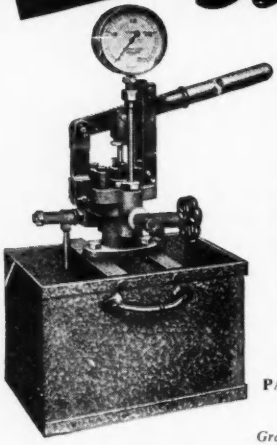

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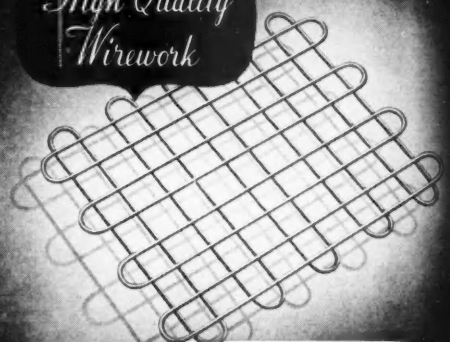

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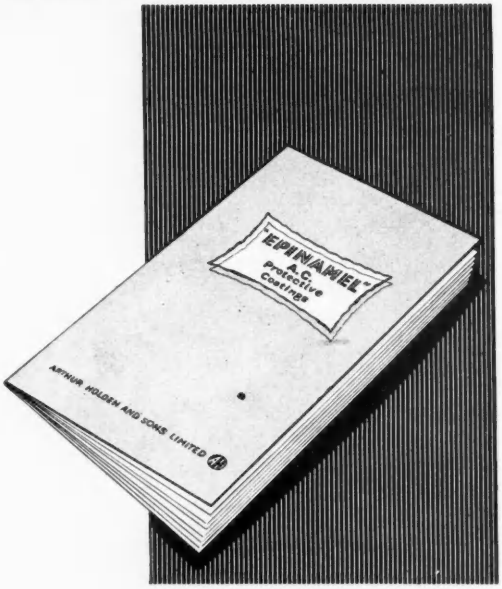

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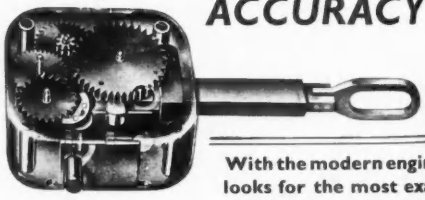

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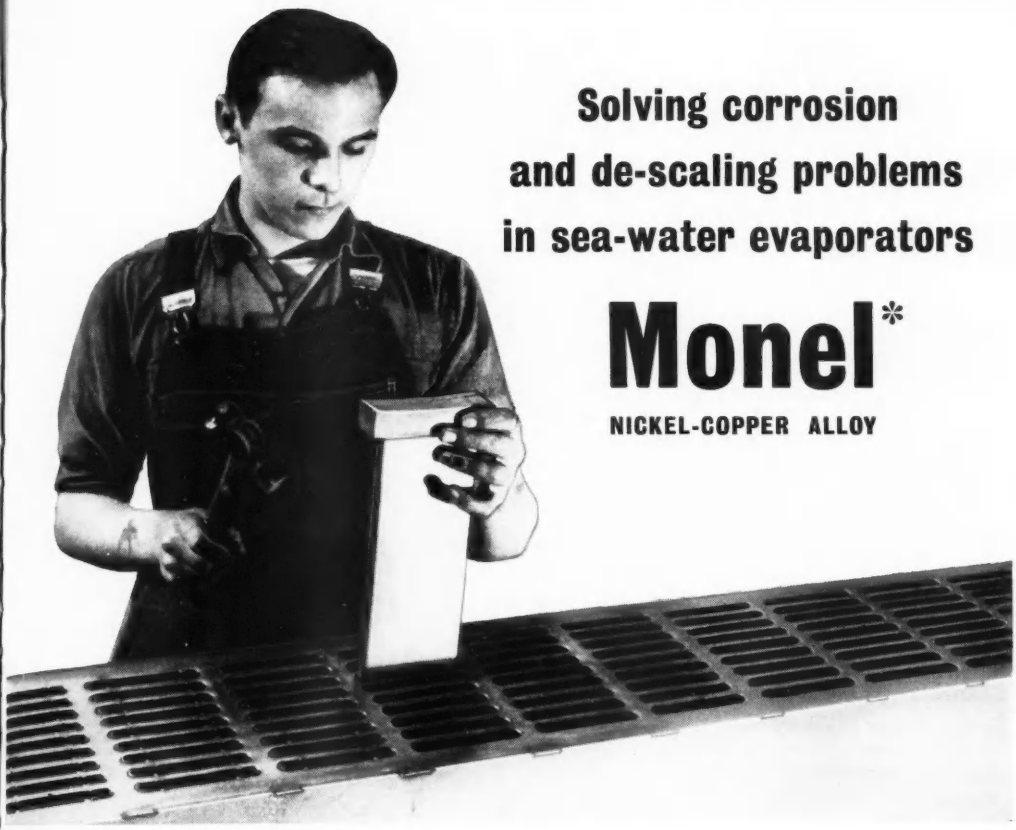

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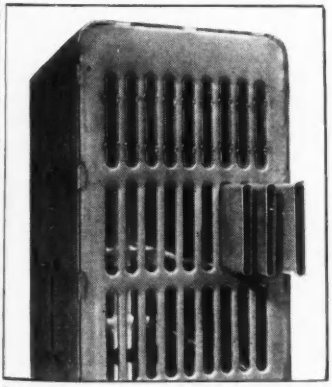

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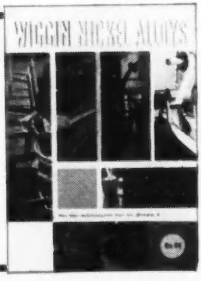

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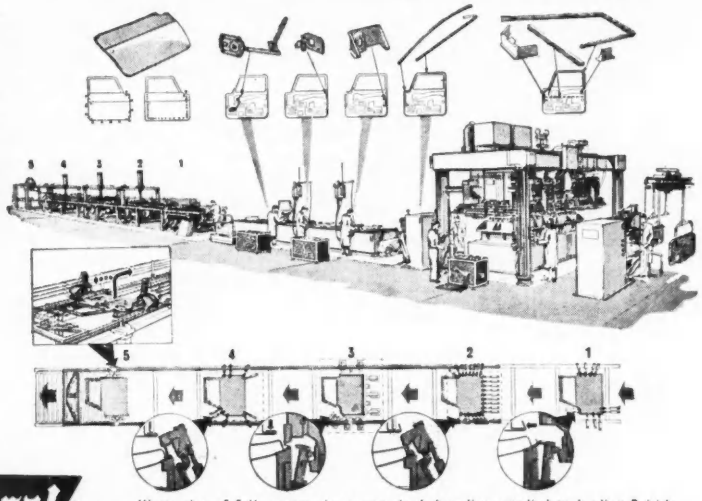

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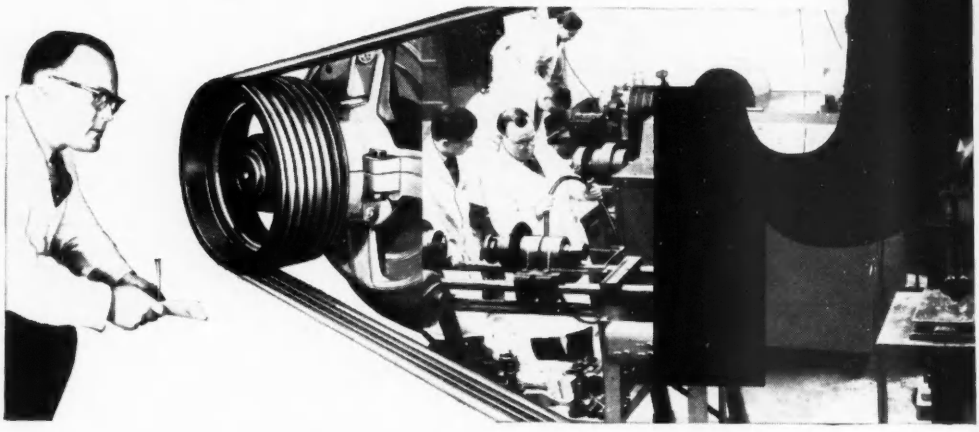

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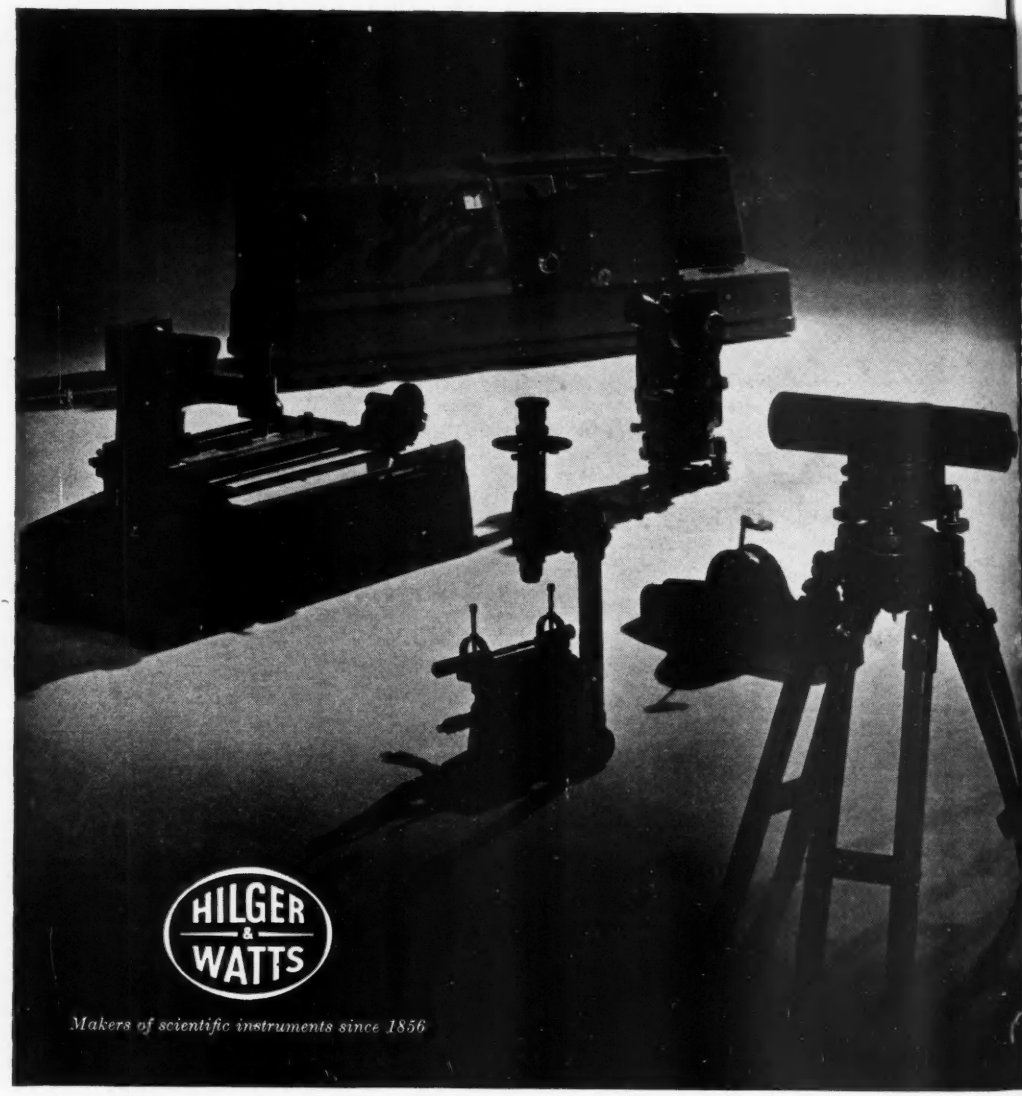

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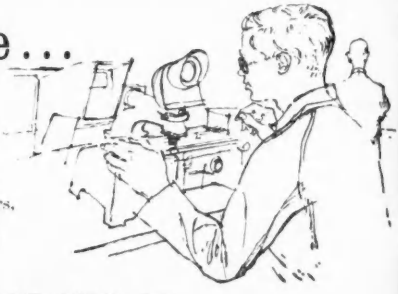

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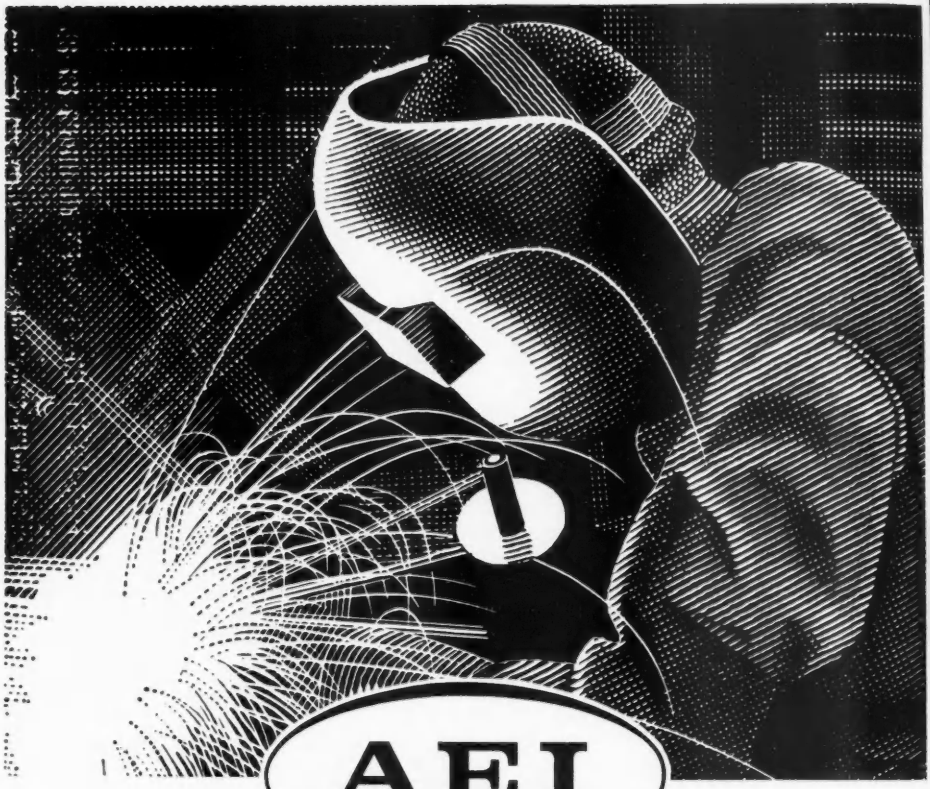

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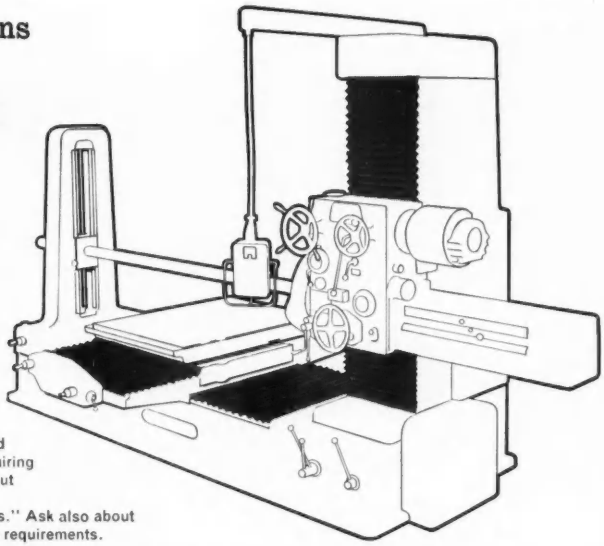

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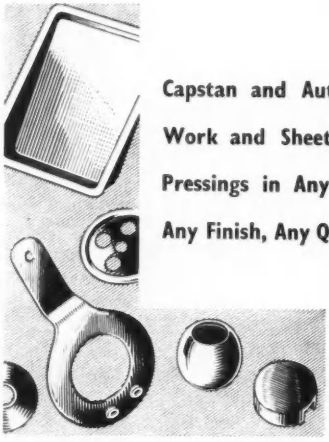

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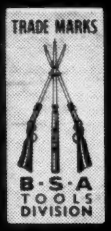

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